

Note that the times shown in the study plan overleaf do not include the time that you will need to answer questions on the DVD and the TMA, making use of the set book, watching the TV programme, attending sessions at your local or regional centre or reflecting on what you have learned and how you have learned it. Past students have also commented that *our* estimates of the times needed for the study of the DVD-multimedia activities are likely to be low.

Study Guide for Block 9

Block 9 returns to the study of living organisms. We start with a review of cell structure and go on to investigate the molecular components and chemical reactions that are common to all living cells. We then examine how information is passed down from generation to generation, and look at the molecules involved in inheritance by examining genes, which link generations through their continuity. Finally, we consider long-term ancestry — the process of evolution, which involves genetic change over time.

This block represents four weeks' work. The study plan overleaf shows how you might divide your time over the four study weeks. However, if you have chosen to omit study of either Block 10 or Block 11 you may wish to spend a little more time on Block 9. As well as studying the printed material, you will study a DVD-video sequence and a TV programme, and work with four DVD-multimedia activities, one of which has practical work associated with it. In Block 4 you were introduced to the practical work with the holly leaf miner, and we asked you to locate a holly bush or tree that showed evidence of this insect. During your study of this block, you will need to collect about 40 leaves, each of which contains a mine produced by the larval stage of this insect. To investigate the mines, you will require a sharp knife, a large sewing needle and your hand lens. You can do this practical work and study the related DVD-multimedia activity ('Holly leaf miner') at any time during your study of this block. Another DVD-multimedia activity ('Cells and energy') comprises almost the whole of Section 7 and revises principles from earlier in the block. The DVD-multimedia activity in Section 8 ('Mitosis, meiosis and recombination') is particularly important because it introduces material not covered in the book. Towards the end of the block you will complete your study of the 'Galapagos' DVD-multimedia activity, which you began during your study of Block 4.

Many of the activities in Block 9 focus on the skill of revising. You will be asked to revise concepts from earlier parts of the course that are needed for this block — in particular, concepts from Blocks 4 and 8 — and to

write summary paragraphs, produce tables and draw flow diagrams of concepts in this block, all of which can be used for revision purposes. In addition, you will be asked to criticize answers to assignments, to mark both your own answers and those of other students, and to plan and write a longer scientific account. Some of these activities, which are designed to improve your written answers, may take a long time to complete. However, you will learn a lot by doing them, and this will help you when answering questions in subsequent assignments.

We recommend that you study the various sections of this block — with the exception of the holly leaf miner activity (Activity 1.1) — in the order in which they are presented, since several sections build on material covered in earlier sections. This is particularly important for the DVD-multimedia activity 'Mitosis, meiosis and recombination' which you should study at the end of Section 8, since an understanding of the content is needed in order to follow Section 9. If you are unable to tackle this activity at the recommended time, then we suggest that you jump to Sections 10 and 11 of the book, and come back to Section 9 after completing the Section 8 DVD-multimedia activity, and before studying Section 12.

The study plan overleaf indicates how the sections could be divided between four study weeks. The total study time for the block is just over 40 hours, but you will need to allocate additional time for collecting holly leaves, for answering the DVD questions, for using the set book (SGSG), for viewing the TV programme, and for meetings at your local or regional centre or of a self-help group. You will also need to allocate time to the TMA questions for Block 9, which form TMA 07.

The *Study Calendar* gives you the broadcast times of the relevant TV programme 'Sickle cell disease: a lethal advantage'. We recommend that you watch this programme at the end of Section 13, if possible.

You should start your study of Block 9 by reading Section 1 of the book.

9 Continuity and change

All study times are in hours

Week	Sections of Book 9	Total study time	DVD-multimedia, DVD-video and practical activities
1	1 Introduction	2 $\frac{3}{4}$	multimedia  2 $\frac{1}{2}$
	2 Cells	1 $\frac{1}{2}$	
	3 The chemistry of life: introducing biological molecules	4	
	4 Basic principles of metabolism	3	
	5 Glucose oxidation	4	
2	6 Photosynthesis	1	
	7 Energy in cells: a review	1 $\frac{1}{2}$	multimedia  1 $\frac{1}{2}$
	8 Meiosis and the genetic lottery	4 $\frac{3}{4}$	multimedia  1 $\frac{3}{4}$
	9 Variations on a gene	2	
	10 What are genes made of?	3	
3	11 Using genetic information	4 $\frac{1}{2}$	video  1 $\frac{1}{2}$
	12 Looking at genomes	1 $\frac{1}{2}$	
	13 Evolution by natural selection revisited	4	
	14 Natural selection and speciation	4	multimedia  2
	15 Levels of explanation reviewed	1	
	'Sickle cell disease: a lethal advantage' should be viewed during your study of Section 13.		

Study File for Block 9

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Notes on activities

You should read through the notes for each activity before attempting it. After completing an activity you should study the relevant comments in the next section of the Study File.

No estimate of time is given for activities that should take 10 minutes or less.

Activity 1.1 Quantifying mortality factors in the holly leaf miner: Part 2

(The estimated time for this activity is 2½ hours split into two sessions, the first of about 30 minutes, the second of about 2 hours. This excludes the time you will spend collecting holly leaves.)

Alms

- 1 To carry out a biological project involving field work.
- 2 To identify some of the mortality factors that operate at different stages of an organism's life cycle and calculate their relative magnitudes.
- 3 To identify the key mortality factor and a regulating mortality factor, and explain how a regulating mortality factor operates in a density dependent way.
- 4 To explain how knowledge about various mortality factors can be used when devising means for the biological control of pest species.

Introduction

In Block 4 you were asked to locate a holly bush that showed evidence of holly leaf miner activity. Since then, the holly leaf miner adults that survived the larval and pupal stages have emerged from the leaves, completing the life cycle for this year, and it is now time for you to continue your practical work on this species.

Planning and procedure

The order in which you should tackle this activity is as follows:

- 1 (30 minutes) Study Sections 1–3 of the DVD-multimedia activity 'Holly leaf miner'. This explains the biology of the holly leaf miner and its predators, and shows you how to start the practical work.



Equipment

KIT ITEM

Hand lens

NON-KIT ITEMS

Plastic bag and sealing tag
Clean knife with a small sharp blade
(e.g. scalpel, kitchen knife or penknife)
40 mined holly leaves
Tweezers
Desk lamp (optional)
Large needle, e.g. darning needle
(optional)
Chopping board (optional)

2 (no time allowance) Collect your sample of 40 holly leaves from a holly bush or tree, any time after the end of June (though if you live in the north, you may be better to wait until at least mid-July because adult emergence occurs later in cooler climates). Once you have collected the leaves, they can be put in a polythene bag, sealed with a tag and stored in a fridge until you are ready to analyse them. They can be stored in this way for a maximum of 6 days, though the sooner you analyse them the better. If you can't find a holly bush with mined leaves, contact your tutor for help. Other students in your area may also be able to give you advice about the location of suitably mined bushes.

3 (1 hour for studying the DVD-ROM and 1 hour for examining and dissecting your own sample of mined leaves, i.e. a total of 2 hours) Study Sections 4–7 of the DVD-multimedia activity 'Holly leaf miner' as soon as possible after collecting the leaves.

In this session:

- (a) You will be shown how to complete the practical work.
- (b) You will examine and dissect the leaves, and then record and analyse your data.
- (c) You will compare your own data with a larger data set collected from a specific pair of holly bushes over several previous years by students taking an earlier version of this course. By analysing this larger set of data, you will investigate population processes in a way that is not possible with a single-year sample of mined leaves.

Safety precautions

- (a) When collecting leaves, you may wish to wear gloves to protect your hands from being scratched by the pointed leaves.
- (b) This activity requires you to dissect the holly leaves using a sharp knife, so you should take care not to cut yourself. Use a clean knife to carry out the dissections so that, if you do happen to cut yourself, the risk of infection is minimized. If you do cut yourself, rinse the cut with clean water. If the cut is serious, try to reduce the blood flow by putting a pad of *clean* tissue or cloth over the wound and pressing gently, but firmly, until the flow stops. If you have any concerns, seek medical aid immediately.
- (c) You should keep the holly leaves away from food (e.g. if you preserve them in the fridge, after collecting and before analysing them, make sure you seal them in a plastic bag; do not allow them to come into contact with food on kitchen work surfaces, etc.)
- (d) When you have finished working with the leaves, wash your hands, any equipment used during the activity and any work surfaces they have come into contact with.

Additional terms used in this activity that are not in the glossary

You are not expected to be able to explain these terms.

leaf abscission The loss of a leaf from a plant and which is under the control of the plant.

biological control The deliberate introduction of an organism that is a predator or parasite of a pest species.

fecundity rate The number of fertilized eggs per individual produced on average in a population.

ovipositor The egg-laying structure of an insect.

(NB the words underlined in the definitions above appear in the *Course Glossary*.)

'Holly leaf miner' is on the Block 9 DVD-ROM.

Activity 2.1 Revision: cells and classification of organisms

This is the first of a number of activities designed to help you revise material from earlier in the course, an understanding of which you will require in order to follow particular sections of this block. Revision, like learning, is an active process. These revision activities will help you to recall key points and will help you organize and condense large amounts of information.

Block 4 introduced you to a simple classification of the living world in which all organisms were divided into domains and kingdoms. This activity revises the key features of this classification. Complete Table 2.1.1 by filling in the blank spaces with the characteristics of the various domains and kingdoms. Try to complete as much of the

table as possible before you check back to Block 4, Section 4. If you are unsure of the meaning of the column headings, then you should check the definitions of these terms in the Course Glossary before completing the table.

Table 2.1.1 Characteristics of the domains and kingdoms.

Domain/kingdom	Unicellular or multicellular	Eukaryotes or prokaryotes	Autotrophs or heterotrophs
domain Archaea			
domain Bacteria			
kingdom Animalia			
kingdom Fungi			
kingdom Plantae			
kingdom Protocista			

The comments on this activity include hints about integrating information from different parts of the course, and about revising.

Activity 3.1 Revision: chemical compounds

This is the second of a number of activities designed to help you revise material from earlier in the course. It refers back to Block 8, which we recommended very strongly that you should not omit as part of your study. Try to complete the activity before you check back to Block 8, Sections 10–16.

For each item in the list given below, write a sentence that defines what the item is, and give an example.

carboxylic acid, amine, amino acid, catalyst, enzyme, condensation reaction, covalent bond, ester, hydrolysis, monomer, polymer.

The comments on this activity include a few more hints about revising.

Activity 3.2 Revision: weak bonds

The purpose of this activity is to revise your understanding of the three types of weak bonds, all of which play a role in forming and maintaining the higher-order structure of proteins. Each amino acid has a different R group — the group that sticks out from a polypeptide chain and is free to interact with other R groups after the peptide bonds have been formed between the carboxylic acid group of one amino acid and the amino group of the next amino acid. The R groups of eight amino acids are given in Figure 3.2.1.

(a) For each R group, identify which of the other seven R groups it could interact with, and name each type of interaction.

(b) If each of these amino acids occurred in the same protein in a cell, identify where the R groups would be found in relation to the structure of the protein molecule as a whole.

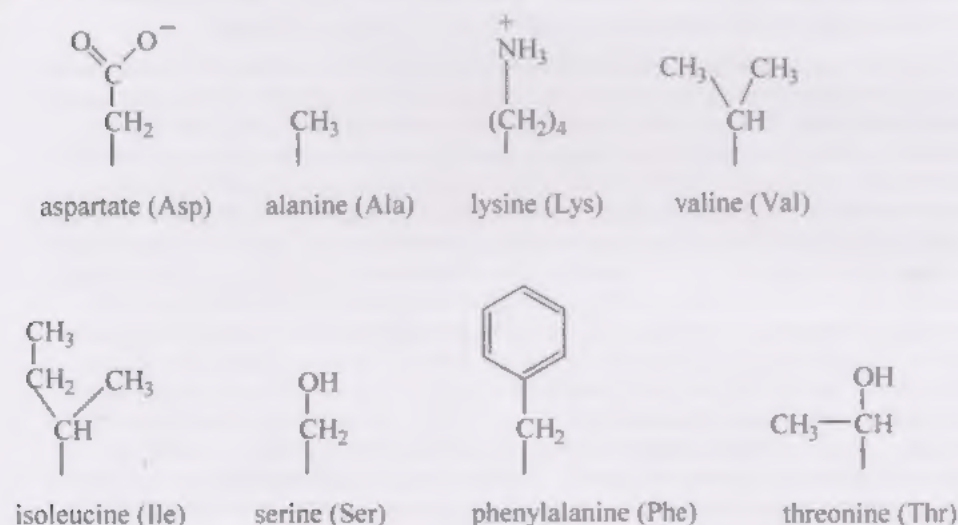


Figure 3.2.1 The R groups of eight amino acids.

Activity 3.3 From amino acid sequence to functional protein

(The estimated time for this activity is 30 minutes.)

This activity also refers back to Block 8. It will help you understand and remember how the primary structure of a protein determines its higher-order structure. It is the first of a number of activities in this block that require you to do some writing in order to develop your writing skills for answering assignment questions. Later activities will require you to mark either your own answers or those of other students, and this will involve you in developing the skill of being critical which, in turn, you can apply to your own written work.

Assume that you have had a letter from a fellow student, Sam, who cannot see how a particular primary structure of a specific globular protein determines its higher-order structure. Your task is to explain this, and you can refer to particular figures in the book rather than draw your own here. Your friend doesn't know about biopolymers in living organisms, but understands different functional groups and the structure of polymers as presented in Block 8. Try to respond to him in about 300 words.

We suggest that you close the book before writing your explanation, and then look at the relevant pages of the book and amend your answer.



Activity 3.4 Viewing biological molecules using WebLab

(We recommend that you spend about 15 minutes on this activity.)

This activity uses the WebLab Viewer to look at biological molecules in three dimensions. It assumes that you know how to use the Viewer, instructions for which were given in Block 8, Activity 12.2. You may have already looked at some of the molecules on the Block 9 DVD-ROM (glucose, glycogen, cellulose, a TAG and a phospholipid) using WebLab, whilst studying Section 3 of this block. (If you have not already done this, now would be a good time to do so.) These molecules are much bigger than the organic molecules that you looked at using the WebLab Viewer in Block 8. Whilst normal ball and stick representations work well with most small to medium-sized molecules, things start to get more complex when we view proteins, which may contain many thousands of atoms. In this activity you will explore a number of other structural representations that are useful for visualizing two proteins, myoglobin and trypsin.

You should start this activity by first placing DVD 2 in your computer and then opening the WebLab Viewer from the S103 Discovering Science folder on the Programs menu of the Start button.

(a) Viewing the structure of myoglobin

Once WebLab is running, open the file named 'myoglob'. You will find this in the MOLECULE folder on the DVD. The protein myoglobin is a biopolymer that is made from amino acid monomers, and it is coiled up rather like a ball of string. The structure, a so-called *framework representation* of myoglobin, will appear. In a framework representation only the bonds to atoms other than hydrogen are shown.

Click on the Zoom button on the left of the screen, and then with the left mouse button held down, move the pointer up the screen to magnify the molecule so that you can see the bonds better. The grey lines represent bonds to carbon atoms, the blue lines are bonds to nitrogen atoms, the red lines are bonds to oxygen atoms and the yellow lines are bonds to sulfur atoms. (The sulfur atoms are a detail not mentioned in the book.) So, for example, a C—C bond is shown just as a grey line, but a C—N bond is shown as a grey line at the carbon end and a blue line at the nitrogen end. The C—C bonds occur within amino acids; a few C—N bonds occur within amino acids (e.g. in lysine, Figure 3.2.1), but the majority are part of the peptide bonds; the C—O bonds occur within amino acids (e.g. in serine); and finally, a few C=O bonds occur within amino acids (e.g. in aspartate), but the majority are part of the peptide bonds. (You may find it helpful to look at the structural representation of three amino acids covalently bonded together, in the comments on Activity 3.1 on p. 25.) The red crosses represent oxygen atoms in water molecules that are present in crystals of myoglobin — so they are not part of the myoglobin molecule itself. (The structure of myoglobin and the positions of these oxygen atoms are determined using X-ray crystallography — see the S103 TV programme 'Hidden visions'.)

To show the atoms more clearly:

- Click on the Display Style button at the top of the screen (the one with the red and white water molecule icon);
- Click on Ball and Stick from the list of Display Styles in the tabbed dialogue box;
- Click on OK.

Though the atoms are clearer in the ball and stick model, the atoms and bonds at the front tend to obscure those behind them. Rotate the molecule to get a better idea of its structure, and notice how it looks like a ball of string. Take the molecule back to its normal size by clicking on the Fit to Screen button at the top of the screen.

The complex shape of myoglobin is important and all molecules of myoglobin have the same convoluted structure. There are many special facilities in WebLab for viewing protein molecules, which help us to understand how the protein is folded, but we will introduce just a few of them in this activity.

To look at a simpler representation of the myoglobin molecule:

- Click on the Display Style button;
- Click on Off in the list of Display Styles on the Atom page;
- Bring the page titled Protein to the front by clicking on its tab;
- Next click on Ca Stick from the list of Display Styles;
- Click on OK.

In this representation, the sequence of colours effectively represents the sequence of amino acid monomer units in the polypeptide chain. Rotate the molecule to get a better idea of how the chain folds. You should be able to follow the chain from the N-terminus — a green stick, through to the C-terminus — a white stick.

An even more simplified representation of the higher-order structure can be obtained:

- Click on the Display Style button;
- Click on Flat Ribbon from the list of Display Styles on the Protein page;
- Click on OK.

The protein chain is now represented as a ribbon. The colours still reflect the sequence of amino acid monomer units in the polypeptide chain, but the regular spiral structure of portions of the polypeptide chain is now clearer.

This higher-order structure can be emphasized even more:

- Click on the Display Style button;
- Click on the down arrow beside the Colour Scheme drop-down list box.
- From the options in that list, click on By Secondary Type;
- Click on OK.

Each red spiral, or helix (plural: helices), in this representation of myoglobin is a portion of the polypeptide chain that spirals regularly to make a rigid cylinder. This type of helical structure is one of a number of structural patterns that recur repeatedly in proteins. In the myoglobin molecule, you can see how the red helices are interspersed with irregular folding patterns of the polypeptide chain (white), to produce the highly specific structure needed for a specific biological function.

Many proteins require a bound specific non-protein group for their biological activity. Myoglobin contains such a group (see Figure 3.5 in the book), the *haem* group, which consists of an organic part and an iron atom to which oxygen binds. The iron required to synthesize this haem group is obtained from food. To highlight the haem group:

- Click on the Display Style button;
- Click on Off in the list of Display Styles on the Protein page;
- Now bring the Atom page to the front by clicking on its tab;
- Click on Line from the list of Display Styles;
- Click on the arrow beside the Colour Scheme box;

- Click on the Chain option from the list that is displayed;
- Click on OK.

Most of the molecule turns white, except for the orange haem group, which is located in a crevice in the middle of the myoglobin molecule. Zoom in on this orange group and then rotate the molecule so that you can see its position in the molecule.

Now select Close from the File menu to remove the myoglobin structure. Do not save any changes.

(b) Viewing the structure of trypsin

The trypsin molecule is an enzyme that breaks down food proteins in the gut. Open the file named 'trypsin' from the MOLECULE folder on the DVD, and rotate the molecule to examine its structure. Again you can see the 'ball of string' structure characteristic of globular proteins, and the grey, red and blue bonds, as you saw for myoglobin. (You may also notice a set of green bonds to a calcium atom. This detail is not mentioned in the book.)

Now look at the size of the active site of this enzyme:

- Click on the Display Style button;
- Click on the arrow by the Colour Scheme box on the Atom page;
- Select the Chain option from the list that is displayed;
- Click on OK.

Most of the molecule is now white but you should be able to see one blue molecule. (There are also a few oxygen atoms in water molecules shown in red.) This small blue molecule (similar in shape to the substrate) is occupying the active site in trypsin and is held there by weak bonds between it and the enzyme molecule. The weak bonds are not shown, so the blue molecule appears not to be attached to the trypsin molecule. The active site is only a small part of the enzyme and is difficult to see. If you enlarge and rotate the blue molecule you may be able to see that it fits into a cleft on the surface of the enzyme — this is the active site.

We will now examine the higher-order structure of trypsin.

- Return the trypsin molecule to normal size by clicking on the Fit to Screen button at the top of the screen;
- Rotate the molecule to place the active site in a position where you can easily see it;
- Click on the Display Style button;
- Bring the Protein page to the front by clicking on its tab;
- Select Flat Ribbon from the Display Styles;
- Select the By Secondary Type option from the Colour Scheme box;
- Click on OK.

This way of displaying the structure reveals two red portions where the polypeptide is wound into regular helices, a structural pattern you saw in the myoglobin molecule. Another structural pattern that regularly occurs in proteins can be seen in this view of trypsin. It is shown in blue and consists of a sandwich-like structure of parallel sheets, in which the polypeptide chain is folded over itself. Again, notice how the regular portions of the polypeptide chain (red helices and blue sheets) are interspersed with irregularly folded portions of the polypeptide chain (white). The complete structure provides the specificity between the enzyme and its substrate.

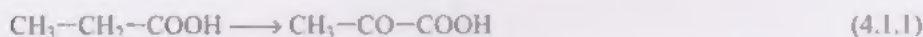
When you have finished looking at the trypsin molecule, you should close the trypsin file using the Close option from the File menu, without saving any changes.

Activity 4.1 Revision: reactions rates, and oxidation and reduction

The purpose of this activity, again based on Block 8, is to revise concepts about chemical reactions. Try to answer before checking back to Block 8, Sections 10 and 14.

(a) In order for a reaction to occur, the reactant molecules must encounter each other. Write a short sentence to explain why each of the following three changes increases the rate of a chemical reaction in a test-tube: (i) increasing the concentration of reactants; (ii) increasing the temperature; (iii) adding a catalyst.

(b) (i) Equation 4.1.1 (which is unbalanced) shows the conversion of one organic compound to another. Explain, in one sentence, what kind of reaction it is.



(ii) Explain also what kind of reaction the reverse reaction to Equation 4.1.1 is.

Activity 5.1 Producing a summary diagram of glucose oxidation

(The estimated time for this activity is about 20 minutes, divided into a number of chunks. If you do it whilst studying the related sections of text it will take very little time.)

In addition to the revision activities, which are designed to help you revise material from earlier in the course, many activities in this block require you to condense whole sections of text into a few paragraphs or into a diagram. The answers to both types of activity will be useful aids in revising before going on to higher level studies. Remember that to benefit from these activities you need to produce your own answers, since this will involve you in thinking harder about the subject.

Figure 5.1.1 (*overleaf*) is a copy of Figure 5.1 in the book, which shows the pathway of glucose oxidation in the cell. This figure provides a framework of the overall pathway for you to refer to whilst studying Sections 5.2–5.5. In this activity you will produce your own summary diagram by adding information to Figure 5.1.1, such as the relevant bold terms and the main reactions. This will enable you to see how the details — the molecules and reactions — relate to the overall scheme of things. Such a diagram will also be useful for reference whilst you review glucose oxidation in the DVD-multimedia activity (Activity 7.1). It is a good idea to add information to your summary diagram after completing each subsection. We suggest you use pencil when adding information so that if the diagram gets cluttered you can easily change it.

Begin by adding information shown in Figure 5.2 to your summary diagram. Keep your summary diagram readily available so that you can both add details to it and refer to it as you study Sections 5.2–5.5.

After studying each of Sections 5.2–5.4

If you have not already done so, add the important details, such as the relevant bold terms and the key reactions that were described in this section, to your summary diagram. You may need to refer back to the text to help you with this.

After studying Section 5.5

First add the important terms and reactions described in Section 5.5, including 'anaerobic respiration'. This completes the information to be added to your summary diagram, but before leaving this activity you should review your completed diagram. We took care to ensure that the information we added was clearly shown and did not clutter our diagram. You should look at your own version and make sure that it is clear, and if necessary amend the layout. You also need to check that you will still be able to understand it in a few weeks time. For example, if you have used abbreviations have you added a key to show what these represent?

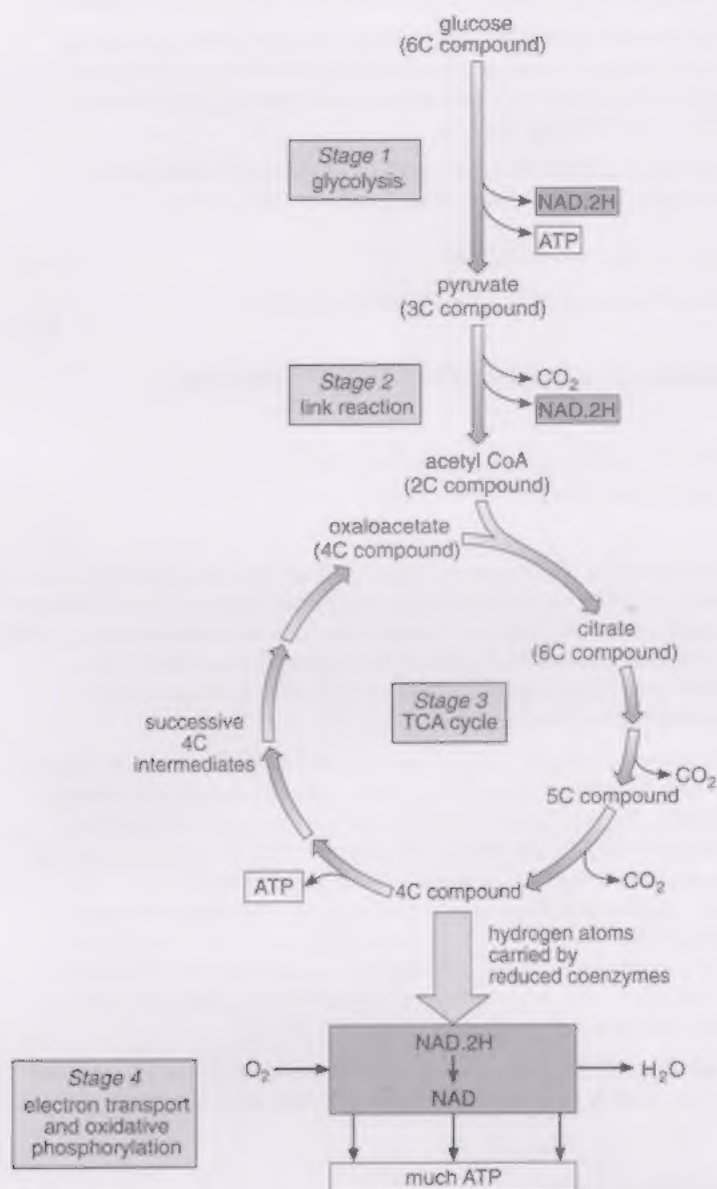


Figure 5.1.1 The glucose oxidation pathway showing the four distinct stages. This is a copy of Figure 5.1 in the book.

Activity 5.2 The 'power-house of the cell'

(The estimated time for this activity is 20 minutes.)

The stages of glucose oxidation that occur in the mitochondria are not straightforward, and Stage 4 in particular — electron transport coupled to oxidative phosphorylation — is quite complicated! In order to help your understanding of the reactions that occur in the mitochondria, including the coupling of the reactions that take place at the inner mitochondrial membrane, draw a flow diagram to summarize the steps by which the energy stored in pyruvate is transformed into energy stored in ATP. Your diagram should include production of reduced coenzymes, and the steps by which the energy stored in these coenzymes is transferred to ATP.

First see how far you can get without reference to the book or to the summary diagram you produced in Activity 5.1. Then complete your flow diagram by referring to your summary diagram and checking the book for further details.

Activity 7.1 Cells and energy

(The study time allocation for this activity is 1½ hours.)

A combination of animations, graphics and questions in this DVD-multimedia activity reviews the structure and function of organelles found in cells, takes you through the stages of glucose oxidation and then the reactions of photosynthesis, and makes them come alive in a way that is not possible in a book.

When studying the animation of glucose oxidation, you will find it helpful to have to hand the summary diagram of glucose oxidation that you completed in Activity 5.1. Here the number of steps in the pathway of glucose oxidation is reduced to 13, and the number of steps in photosynthesis is reduced to 8. Some information additional to that provided in the text is incorporated in various parts of this activity, but you are not expected to remember this and won't be assessed on it. This enrichment is included in order to portray the reactions accurately in the animation, and to enhance understanding.

We estimate that it may take more than the time allocated to complete all three parts of this activity. Therefore, we suggest that you study the short review of organelles fairly quickly, and then concentrate on the pathway of glucose oxidation, paying particular attention to any steps that you have not understood in the text, and *study the photosynthesis exercise only if you have time*. When studying photosynthesis, concentrate in particular on the similarities and differences between this process and glucose oxidation.

You should read the notes below before you start the photosynthesis exercise.

'Cells and energy' is on the Block 9 DVD. You should start this activity now.

Additional information about photosynthesis and terms used in this activity

You are not expected to be able to explain the italicized terms

The structure of the chloroplast and the reactions occurring inside it are more complex than described in the book. Before studying the relevant part of this activity, you may find it helpful to read the text below in which three terms used in the activity (but not included in the glossary) are defined and the role they play in photosynthesis explained.

A *thylakoid* is a flattened sac of the innermost membrane of the chloroplast. A pile of thylakoids is referred to as a granum (plural: grana). Inside each thylakoid is a space, the *thylakoid lumen*.

When water is split, releasing oxygen, the protons are released and the electrons are passed along the photosynthetic electron transport chain. NADP, present in the stroma, is reduced to NADP 2H by combining with the electrons, and protons from the stroma. Three of the carriers in the electron transport chain in the thylakoid membrane are proton pumps and transport protons from the stroma into the thylakoid lumen, forming a proton gradient. Protons flow back, down their concentration gradient, from the thylakoid lumen through the channel in the ATP synthase enzyme, back into the stroma. The energy released from this flow of protons is used to synthesize ATP from ADP and P_i .

There are actually *two* membranes that surround the chloroplast. The first carbon compound to be produced in the chloroplast is a 3C sugar phosphate; this is transferred to the cytosol by a specific transport protein situated in the inner of these two membranes. This transfer is quite complex and involves the movement of an inorganic phosphate ion (P_i) into the chloroplast in exchange for each 3C sugar phosphate molecule entering the cytosol. This exchange process is called *phosphate translocation*.

Activity 8.1 Revision: chromosomes and the life cycle

(The estimated time for this activity is 25 minutes.)

This activity will help you to revise what you learnt in Block 4 about the life cycle and changes in chromosome number. You will also improve the writing skills that you use for answering assignment questions, by making a critical assessment of a piece of written work. As Block 9 progresses, we will ask you to move from being critical of someone else's work to being critical of your own. As the first step in this process, this activity asks you to imagine that you are a tutor and to mark a piece of work submitted by a student who has just finished reading Block 4, Section 6. You are not required to do any writing yourself.

(a) First look at the question that the student has been asked to answer:

Describe the stages in a life cycle, such as the human life cycle, and indicate the changes in chromosome number at each stage. Your explanation should include a labelled diagram and should be no longer than 250 words. You should include, and show good understanding of, the following terms: autosome(s), centromere, chromatid, chromosome, diploid, fertilization, gamete, haploid, meiosis, mitosis, nucleus, ovum, sex chromosomes, zygote. (25 marks)

(b) Next look at the student's answer and mark it against the mark scheme below. To do this you will need to identify the scientific errors, omissions, judge the suitability and labelling of the diagram and judge the quality of the writing. The best order to do this is:

- 1 Read the answer
- 2 Familiarize yourself with the mark scheme.
- 3 Re-read the student's answer, awarding marks as you do so.

Student's answer

Haploid cells contain one set of chromosomes and diploid cells contain two sets, with each chromosome (usually) having a morphologically identical partner. The sex chromosomes — usually called autosomes — form a pair. Chromosomes are tiny threadlike structures that occur free in the nucleus of each cell. For part of the cell cycle, individual chromosomes are single-stranded, but by the beginning of meiosis they are double-stranded. Each strand is called a chromatid and the two strands are held together at the centromere. Haploid cells contain one set of chromosomes and diploid cells contain two sets.

Adult animals and plants are diploid, with very few exceptions. No species of eukaryote that reproduces sexually is composed entirely of haploid or entirely of diploid cells at all stages of its life cycle. The alternation of these two types of cells within the life cycles of organisms is shown in the diagram.

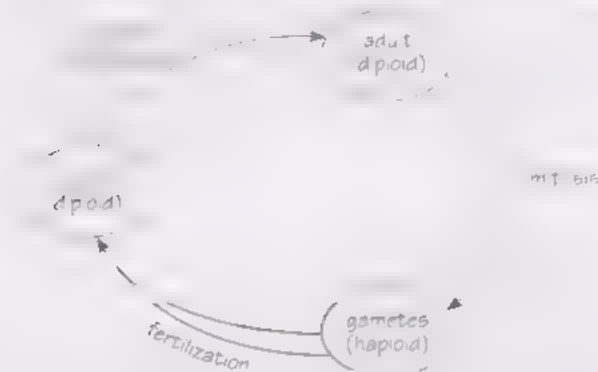


Figure 8.1.1 (Student's diagram. Note the diagram contains errors!)

The production of haploid gametes is brought about by the process called mitosis. The zygote divides by means of meiosis to produce an adult organism. Meiosis occurs as a series of stages, named prophase, metaphase, anaphase and telophase. Each cell of the adult, other than the reproductive cells, contains identical copies of the genetic material. (202 words)

Mark scheme

Award one mark each for <i>correct</i> use of each of the required terms: autosome(s), centromere, chromatid, chromosome, diploid, fertilization, gamete, haploid, meiosis, mitosis, nucleus, ovum, sex chromosomes, zygote.	14 marks
Award two marks for correct description (in the text or in the diagram) of the changes of chromosome number	2 marks
Award two marks for the diagram, plus one mark for labelling and one for the title	4 marks
Award five marks for quality of writing, broken down as follows:	
Clarity of writing (deduct one mark for each ambiguity);	2 marks
Conciseness (deduct one mark for each irrelevant point and for any repetition);	2 marks
Coherence — writing with a logical flow.	1 mark
Total marks	25 marks

Award marks for the student's answer, and then check the mark you gave with those awarded by an S103 tutor in the comments on this activity

Activity 8.2 Tackling problems in genetics

(The estimated time for this activity is 25 minutes.)

General hints for tackling problems in genetics

In Blocks 5 and 8 you were encouraged to develop strategies for solving different sorts of problems. Here we will offer some guidelines on how to set about solving genetics problems, and you will then tackle a problem using these guidelines. You need to bear in mind that genetics problems cannot be solved by rote learning, each one has to be tackled afresh using your understanding of genetic principles, common sense, and sometimes trial and error. Here is a list of guidelines, which should help you to tackle a wide range of genetics problems; you may need to adjust the *order* in which you work through the steps according to the information given in the question.

- 1 Read the question and make sure that you understand all of the terms that are used (e.g. pure-breeding, heterozygous, etc.).
- 2 Draw out the crosses as mating diagrams, using one of the two alternative layouts shown in Figures 8.8 and 8.9 in the book, and include all the information that is given in the question, e.g. pure-breeding tells you that a variety is homozygous. This will help you to think about the problem logically, and show what information you need to deduce, e.g. the genotypes of one or more of the generations involved.
- 3 Assign letters to the alleles of the genes, or the copies of genes, that are involved, if they are not specified in the question. You may need to use information provided in the question to deduce which phenotype is dominant and which is recessive: for example, if a particular phenotype disappears in the progeny of one generation and reappears in the next generation, you can infer that this phenotype is recessive to the phenotype that is masking its presence.
- 4 Complete the mating diagram; for example, use the genotypes of each generation to deduce the genotypes of the gametes, and use the genotypes of the gametes to determine the genotypes of the offspring. (With some problems you may be working from genotypes of offspring back to the genotypes of the parents.)
- 5 Use information about the dominant allele or character to determine the phenotypes of each generation. (In some problems, such as the one given here, you will start by using phenotypes to determine genotypes.)
- 6 Calculate the ratios of the genotypes and of the phenotypes from the mating diagram.
- 7 Ask yourself whether the results are consistent with what you have learned about genetics and probability.

We suggest that you tackle the following problem using the above guidelines.

A genetics problem

The fruit-fly *Drosophila melanogaster* is widely used by geneticists for breeding experiments in the laboratory because it is easy and cheap to rear and each female produces hundreds of eggs. Suppose that you carry out a breeding experiment using two pure-breeding varieties of *D. melanogaster*, one with normal-shaped eyes and one with eyes reduced to about half the normal size, called 'eye-less'. The first cross is between these two varieties. The F_1 offspring all have normal eyes. The second cross is between an F_1 normal-eyed fruit-fly and a pure-breeding eye-less variety. What is the expected ratio of genotypes, and the expected ratio of phenotypes of the offspring of the second cross?

Activity 8.3 The 3:1 phenotypic ratio

(The estimated time for this activity is 30 minutes.)

This activity is designed to consolidate your understanding of ratios, fractions and probability. It takes the form of a series of very short questions. Try to answer all of the questions before looking at the answers given in the comments. The comments also contain some general advice on ratios and fractions.

- (a) Count the purple and the white grains (yellow in this dried cob) on the one visible side of the F_2 cob in Figure 8.13. Calculate the ratio of purple to white grains, expressing your answer in the way shown in the right-hand column of Table 8.2.

(b) Write your results down in the appropriate columns in Table 8.2 in the book. (Space has been left at the bottom of the table for you to do this.) How do your results compare with our results given in Table 8.2?

(c) The grains on the cob are the result of fertilizations between two kinds of pollen grains, *G*-bearing and *g*-bearing, and two kinds of ovules, *G*-bearing and *g*-bearing. Thus the expected phenotypic ratio is three dominant (purple) : one recessive (white). Explain the deviation from the 3 : 1 ratio for the part cob that you counted.

(d) Now think again about the grains you counted. How many grains are visible altogether? Give the number of white grains as a fraction of the total number of visible grains.

(e) What is the probability that an F_2 maize grain will have the genotype *g g*? Compare this with your answer to part (d).

(f) Compare your answers to part (a) and part (d). Are these answers consistent? How do your answers relate to what you have learnt about fractions and ratios previously in S103?

multimedia

Activity 8.4 Mitosis, meiosis and recombination

(The study time allocated to this activity is 1½ hours.)

This DVD-multimedia activity is important because, for the most part, it contains new material that is not presented in the book. You should study it before embarking on Section 9 of the book

The activity begins by revising the nuclear division of mitosis (Block 4, Section 3.3), which results in the production of two identical progeny cells. An understanding of the sequence of nuclear events and the physical structures involved in mitosis is a necessary background for the next part of the activity, in which you will study the nuclear division of meiosis and the production of haploid gamete cells. You will revise the segregation of alleles, which follows from the behaviour of chromosomes at meiosis.

The behaviour of chromosomes at meiosis is also important for understanding the patterns of inheritance when more than one pair of contrasting characters are observed simultaneously. During meiosis, genes and alleles are shuffled and this results in the production of gametes with new combinations of alleles.

This activity ends by looking at maps of the order of genes along a chromosome.

'Mitosis, meiosis and recombination' is on the Block 9 DVD. You should start this activity now.

Activity 9.1 Sources of phenotypic variation

(The estimated time for this activity is 20 minutes, divided into a number of chunks. However, if you do the activity whilst reading the related text, it will take very little time.)

In Section 8 you learnt about some sources of phenotypic variation. In Section 9 you will meet a number of other factors that contribute to the variation between individuals. Keeping a summary of these sources of variation will be useful for reference at a later date — for example, when you study Section 13, which deals with evolution, a process that cannot proceed without variation. When producing a summary that will be used for reference or revision purposes you need to think about how to present it — as a list, a set of notes, a table or a summary diagram — as well as how much detail to write in order to be able to recall the important points. You have already completed a summary diagram and produced a flow diagram to aid your revision of Section 5 (Activities 5.1 and 5.2).

The sources of phenotypic variation introduced in Section 8 were important, so you should begin your summary with these. Do this now by looking back at the summary of Section 8 and identifying each of the sources of phenotypic variation. Then check your list with the list in the comments on this activity before you continue with Section 9. It is a good idea to add to your summary after completing each subsection.

At the end of each of Sections 9.1–9.5

If you have not already done so, add to your summary any new source of phenotypic variation that you identified in this section. You may need to refer back to the book to help you with this.

At the end of Section 9.6

Add to your summary any new source of phenotypic variation that you identified in this section. Then read about the more general issues relating to revision at the end of the comments on this activity.

Activity 9.2 Applying genetic principles to sex-linked genes

In this activity you will follow the inheritance of a sex-linked gene. T. H. Morgan, working in New York, USA, carried out investigations on *D. melanogaster* for which he was awarded a Nobel Prize in 1934. He noticed a white-eyed male fly in his stock of normal red-eyed flies. He mated this white-eyed male with a red-eyed female and all the F_1 offspring had red eyes. (There are a number of different genes that influence eye colour in *D. melanogaster*, and we now know that the gene Morgan investigated is different from the one that has an allele that produces brown eyes.)

From this we can conclude that red eye is dominant to white eye, so we can represent the normal allele as *R* (red-eyed) and the recessive allele as *r* (white-eyed). These observations in themselves are not unusual. When red-eyed F_1 males were mated with red-eyed F_1 females, the F_2 generation contained about 3 000 red-eyed flies and about 1 000 white-eyed flies. This result again may not appear to be striking since the ratio is 3 : 1, and this is consistent with breeding experiments in which the original parents were both pure-breeding for eye colour. However, Morgan made a crucial discovery: all the F_2 white-eyed flies were males!

(a) To understand these results, complete the diagram on the next page, which is a summary of Morgan's observations. To help you with this, use the guidelines for tackling problems in genetics given in the notes to Activity 8.2. However, the mating diagram has already been drawn for you and letters have been assigned to alleles. Note that each of the gene copies for eye colour is shown on the appropriate sex chromosome, denoted by the letter X or Y; you will find it helpful to use this notation when completing the diagram.

(b) What are the possible phenotype, for both sex and eye colour, of the F_2 flies, and what are their expected ratios?

(c) Explain, in one sentence, why the incidence of phenotypes for recessive sex-linked characters is much higher in males than in females.

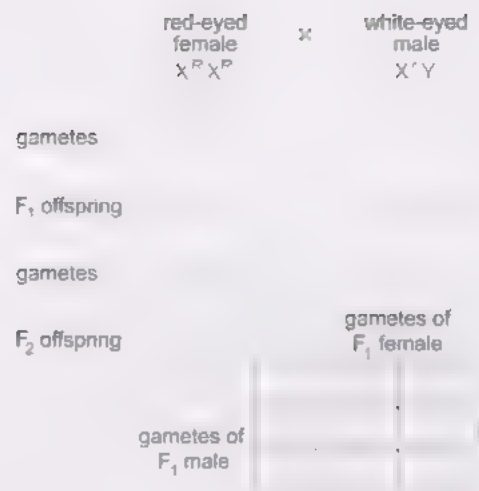


Figure 9.2.1 The breeding experiment that led to the identification of a linkage between eye colour and the sex of the fruit-fly, *D. melanogaster*.

Activity 9.3 Applying existing knowledge of genetic principles to multiple alleles

Human ABO blood groups can be assigned to one of four phenotypes, which are determined by pair-wise combinations of three alleles *A*, *B* and *O*. The relationship between the phenotypes and the six possible genotypes is shown in Table 9.3.1.

Table 9.3.1 The genetic basis of ABO blood groups in humans.

Genotype	Phenotype (blood group)	Genotype	Phenotype (blood group)
AA	A	BB	B
Ai	A	BO	B
Bi	B	OO	O
AB	AB		

- What is the dominance relationship between allele *O* and each of alleles *A* and *B*?
- Comment on the dominance relationship between alleles *A* and *B*.
- Using the guidelines for solving problems in genetics given in the notes for Activity 8.2, determine the possible phenotypes and genotypes of the children produced by two individuals, one of blood group AB and the other of blood group O. Compare the phenotypes of the children with those of the parents.

Activity 10.1 Revision: structure of biopolymers

(The estimated time for this activity is 45 minutes.)

This activity revises information from Section 3, and involves representing this information in a different way. In addition, it is designed to improve your writing skills (see also Activities 3.3 and 8.1). The emphasis here is on presenting your answer in the way that the question requires, and on being critical of your own work.

- Write a paragraph, of no more than 200 words, in answer to the following question:

What are the features common to the three main groups of biopolymers: proteins, polysaccharides and nucleic acids? (20 marks)

Your answer should be based on information in Sections 3.2–3.5. Illustrate your answer, where possible, with specific examples, and with diagrams that show the overall structure of biopolymers rather than individual component parts. To save time, rather than drawing the diagrams, choose which figure in the book you would include in your paragraph.

You should complete your answer before reading part (b)

(b) Now mark your answer, using the following mark scheme for guidance:

Science content

The following five key points should be awarded two marks each:

- | | |
|---|---------|
| (i) Molecules of all three biopolymers are large. | 2 marks |
| (ii) Each biopolymer is composed of repeat monomers: amino acids for proteins, monosaccharides, or sugars, for polysaccharides, and nucleotides for nucleic acids | 2 marks |
| (iii) Each monomer is linked to adjacent monomers by covalent bonds formed by condensation reactions with loss of water. | 2 marks |
| (iv) The higher-order structure is maintained by weak bonds. | 2 marks |
| (v) The structure of each biopolymer is closely related to the function it performs. | 2 marks |

Diagrams

Award four marks for diagrams (one for each diagram) placed at appropriate positions in the text, as long as each is referred to in the account, has a title, is labelled and illustrates the points referred to in the text.	4 marks
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Any of the following would be appropriate: Figure 3.3 (shape of fibrous protein, collagen); Figure 3.5 (globular protein, myoglobin); other figures that illustrate the shape of globular proteins and would also be acceptable, e.g. Figure 3.6a (receptor protein), Figure 3.6b (enzyme), Figure 3.7 (antibody); figures showing shapes of polysaccharides, e.g. Figure 3.12b (amylopectin, branched); Figure 3.12a (cellulose, unbranched).

Writing

Award two marks for each of the following three aspects.

- | | |
|---|---------|
| (i) clarity of writing — deduct one mark for each ambiguity. | 2 marks |
| (ii) conciseness — deduct one mark for each irrelevant point, and if the account is still overlength once these points are removed, then deduct one mark for each 30 words over the 200 word limit. | 2 marks |
| (iii) coherence — the five key points should be dealt with one at a time. One logical sequence is as presented in the order above, but other sequences are possible (e.g. (i) and (ii) could easily be reversed, and (v) could come first). | 2 marks |

Total marks

Any student who tackles the account by writing about each biopolymer in turn, rather than each key feature in turn, should be awarded a maximum of 14 marks, i.e. they should not be awarded any marks for presentation.	20 marks
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Activity 10.2 Understanding DNA replication

(The estimated time for this activity is 30 minutes.)

This activity will help you consolidate your understanding of DNA replication. In addition, it is the fourth activity in the series designed to help you to improve your answers to assignment questions (see Activities 3.3, 8.1 and 10.1). Here we ask you to be critical of the writing of others; you are *not* asked to do the writing yourself

Imagine that at this point in Block 9 students studying S103 had been given the following question:

Write a paragraph of no more than 150 words summarizing the process of DNA replication. Include a diagram in your answer.

Compare the two student answers given below, noting down what is good and poor about each, in terms of science content, writing style and how well each answer fits the question set.

Answer 1

During DNA replication, a DNA double helix unwinds and each single polynucleotide strand forms a template. On which a new strand is synthesized. DNA polymerase adds nucleotides and the base-pairing rules. G binds C, T binds A and vice versa. The sugar-phosphate backbone of the DNA molecule is formed. Two identical helices are thereby synthesized. This is conservative replication because each new double helix contains one polynucleotide strand from the 'parent' molecule and one newly synthesized strand.

(79 words)

[No diagram]

Answer 2

DNA replication is a conservative process by which one molecule is copied to give two. The two DNA strands are made up of nucleotides. These unwind and base-pairing occurs. G binds to A and vice versa, T binds to C and vice versa as shown in Figure 10.2.1. (49 words)

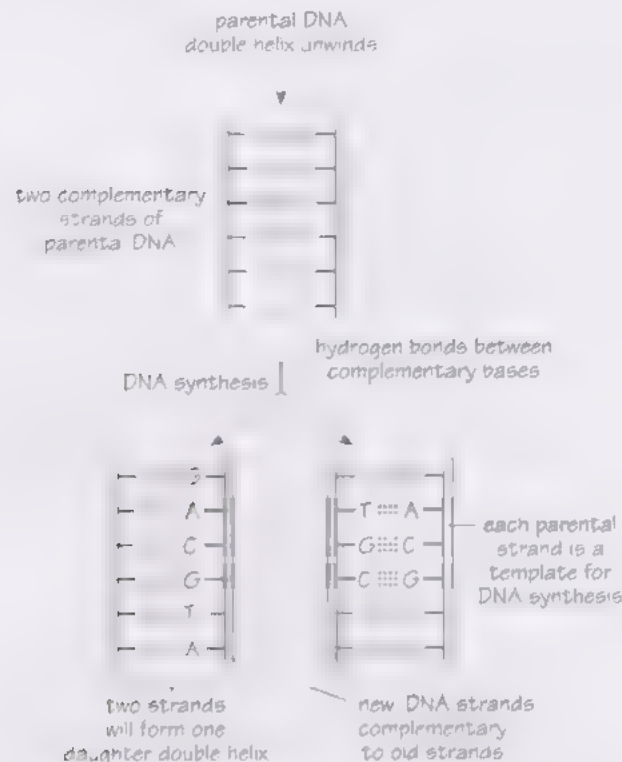


Figure 10.2.1 The process of DNA replication.

Activity 11.1 The flow of information from DNA to RNA to polypeptide

(The estimated time for this activity is 15 minutes.)

This activity will help to consolidate your understanding of the processes of transcription and translation. In addition, it is the fifth activity designed to improve your answers to assignment questions.

In this activity you are not required to write an answer, but rather to carry out the planning that would be required in order to write an answer to the following question:

Write an account, which would be suitable for revision purposes, that summarizes in about 300 words the processes of transcription and translation. A description of the genetic code, and of the structure of DNA and RNA, is not required.

Identify the key scientific points relating to these two molecular processes and put them in a logical order, which could then be used as the basis for putting together an answer.

The comments on this activity include a list of key points, one possible correct answer, and an indication of what you should have achieved from carrying out this activity.

Activity 11.2 A foretaste of the genetic code

(The estimated time for this activity is 15 minutes.)

It is possible to complete this activity about the genetic code from the information already provided, but you may find it quite challenging! Try it now, but do not worry if you cannot complete the activity – it will be more straightforward after you have studied Section 11.5, and you could return to it then.

Below is a short sequence of part of a DNA template strand:

TACCCTCCTCAATTCGGA

(a) Copy out this DNA sequence, and then write below it the RNA sequence that would result from its transcription. (You may wish to look at the base-pairing rules for transcription in Table 11.1 of the book.)

(b) The RNA sequence that you have just produced should have 18 bases in it, which can be split up into 6 codons. Draw lines between each of the codons to separate them clearly.

(c) From Figure 11.8 in the book you should be able to identify the amino acids that correspond to six different mRNA codons. You may find it helpful to list the codons with their corresponding amino acids. (It will be easier to use the abbreviated names, as given in Figure 11.8.) Then compare these codons with those from (b) above. From this you should be able to write out the amino acid sequence that the six codons in (b) would produce after translation.

Activity 11.3 The genetic code

(The estimated time for this activity is 15 minutes.)

Below is the start of the base sequence in the template strand of a section of a DNA molecule isolated from a particular population of cells.

TACCTCGGTCATCCCT...

Use the information given in Tables 11.1 and 11.2 in the book to answer the following questions:

(a) If the above sequence is transcribed, what will be the corresponding mRNA base sequence?

(b) If the mRNA sequence is translated, what will be the amino acid sequence of the product?

(c) Write out the corresponding DNA sequence of the non-template strand.

(d) If this non-template DNA sequence could be transcribed, what would be the corresponding mRNA sequence?

(e) If this mRNA could be translated, what would be the amino acid sequence of the product?

(f) In practice, why would the sequence you wrote out in answer to (d) not be translated?

Hint: what is missing from this sequence that appeared in the answer to (a)?

Activity 11.4 Information flow in cells

(The estimated time for this activity is 35 minutes.)

This DVD-video sequence illustrates the key points of Sections 10 and 11. It concentrates on the flow of information from DNA to RNA to polypeptide, showing the relationship between the sequence of bases in DNA and the sequence of amino acids in a polypeptide chain. No new concepts are introduced in the sequence but by animating the processes involved it helps to bring them alive.

You will find it helpful to have the following summary to hand whilst watching the DVD-video, pausing after each point to check that you have understood and to add details in the 'Comments' column.

video

(1) *Introduction* The three key features of DNA are: the molecule is stable, it can be faithfully replicated; and it contains coded information which is used to direct the synthesis of proteins.

(2) *DNA structure* The basic building blocks of DNA, the nucleotides, are linked to form polynucleotide chains. The precise base-pairing rules form the basis of the double-helical structure of DNA.

(3) *DNA replication* A DNA double helix unwinds and each polynucleotide chain forms a template for DNA replication. Free nucleotides are added sequentially, according to the base-pairing rules. Two daughter DNA double helices are produced, each identical to the original

(4) *The information in DNA* This is coded within the base sequence and composed of the four-letter language of A, G, C, T. One particular sequence of bases is equivalent to one gene.

(5) *Gene to polypeptide* In the flow of information from DNA to polypeptide, first an mRNA strand is synthesized with a base sequence complementary to the template strand of the appropriate gene — a process called transcription. The information in mRNA is translated into the sequence of amino acids in a polypeptide chain.

(6) *RNA structure* RNA is a single polynucleotide chain, it contains ribose instead of the deoxyribose, and the base U replaces T.

(7) *Transcription — writing the message* A section of DNA unwinds and the message, mRNA, is produced by transcription on the template strand.

(8) *Translation — reading the message* A tRNA molecule, carrying its specific amino acid, binds to the mRNA codon via the anticodon. A second tRNA molecule binds to the mRNA and the two amino acids become joined by a peptide bond. The process repeats, elongating the polypeptide chain until the stop codon is reached.

(9) *At the ribosome* Translation begins when mRNA binds to a ribosome. The process continues as the ribosome moves along the mRNA one codon at a time, until a stop codon is reached. The completed polypeptide chain is released from the ribosome.

Activity 11.5 Mutation and the polypeptide sequence

(The estimated time for this activity is 15 minutes.)

As well as changes in the sequence of bases, a mutation sometimes may involve the omission of a base or the insertion of an extra base. In this activity we will look at the consequences of such changes starting with the same DNA sequence as in Activity 11.3.

(a) A population of cells has been treated with a chemical agent which has brought about a change in the DNA sequence. This is very specific, such that the sixth base in that sequence is deleted, shown here underlined:

TACCTCGGTCATCCCT...

The new template sequence is as follows:

TACCTGGTCA TCCCT...

Use Table 11.2 in the book to work out the effect this change will have on the amino acid sequence if this DNA sequence is transcribed and the RNA product translated. What is the significance of this result?

(b) Another population of the same type of cells as used in (a) has been treated with a different chemical agent, which results in a different kind of mutation. This time an extra base is added to the DNA, such that the template sequence, with the inserted base shown underlined, now reads as follows:

TACCCTCGGTCATCCCT...

What effect will this have on the corresponding amino acid sequence? What is the significance of the result you have obtained?

Activity 12.1 Genomes and gene function

In this activity you will compare genomes and gene function in prokaryotes and eukaryotes by completing Table 12.1.1. Try to complete the table without looking at the book, by adding an appropriate single word, such as 'present' or 'absent', or the name of a site, such as 'cytosol' or 'nucleus', to the blank space in each column opposite each feature. Then refer back to the book and amend/complete your table.

Table 12.1.1 Comparison of genomes and gene function in prokaryotes and eukaryotes.

Feature	Prokaryotes	Eukaryotes
genome complexity		
site of DNA replication		
site of transcription		
site of translation (ribosomes)		
introns		
exons		
splice sites		
repeat sequences		
mRNA splicing		

Activity 13.1 Revision: evolution by natural selection

This activity revises the main principles of evolution discussed in Block 4, and of the relevant genetics described in this block. Complete the two paragraphs below about evolution and natural selection, by writing the appropriate word or phrase, chosen from the following list, in the spaces provided. Some words/phrases should be used more than once. Then check back to Block 4, Sections 9–11, and Sections 8 and 9 of this block, and amend/complete your answer as appropriate.

Missing words or phrases: population; phenotype(s); phenotypic; genetic drift; polymorphic; fitness; relative frequencies; mutation(s); heritable; struggle for existence; genetic variation.

Over time, each generation of organisms is replaced by a new generation. For any particular character, if all the individuals have identical _____, then this process of replacement has no effect. However, many characters are _____ that is, they exist in two or more alternative forms. These forms may change in their _____ between generations, by one of two principal mechanisms of evolutionary change: _____, whereby a character may increase or decrease in frequency due to chance events; and natural selection, whereby some characters are more likely to survive than others. _____ provide the raw materials on which _____ and natural selection can act.

The essence of Darwin's theory is that natural selection will operate if three fundamental criteria are met. First, individuals within a _____ must show _____ variation. Second, some of this _____ variation must be due to _____ and hence have a _____ basis. Third, there is a _____ so that, on average, more or fewer individuals of one _____ must survive than those of another. Natural selection favours the _____ (e.g. brightly coloured male guppies) that results in most offspring surviving to maturity. _____ is the numerical measure of relative reproductive success.

Activity 13.2 Revision: genetic recombination

In Activity 8.4, you studied recombination by independent assortment of chromosomes and by crossing over. The purpose of this activity is to review the genetic outcomes of these two processes, which are shown in Figure 13.2.1.

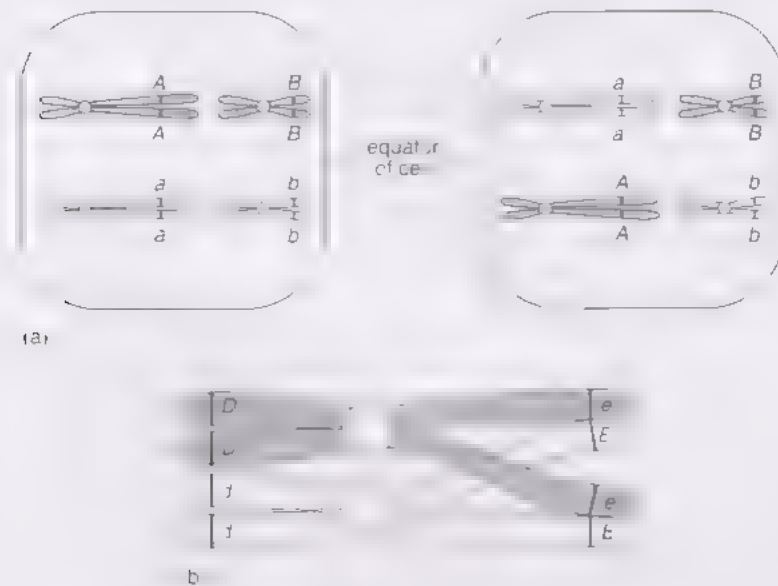


Figure 13.2.1 Recombination during meiosis. (a) Two arrangements, at metaphase I of meiosis, of two homologous pairs of chromosomes – the separation of the homologue from its partner will result in independent assortment of alleles. (b) Paired homologous chromosomes about to exchange genetic material, at prophase I of meiosis.

(a) Consider first the process of independent assortment. What are the genotypes of the gametes, and their ratios, produced by an individual with the genotype shown in Figure 13.2.1a? Assuming that the two grey chromosomes were originally inherited from the mother and the two white chromosomes from the father, which genotypes are recombinants?

(b) What are the genotypes of the gametes, and their ratios, produced by an individual with the genotype shown in Figure 13.2.1b, following the exchange of genetic material? Which genotypes are the recombinants?



Activity 13.3 Sickle-cell disease: a lethal advantage

(The estimated time for this activity is 35 minutes.)

You may have already watched this programme if it was transmitted earlier in the year, and even made a video recording of it, but we recommend that you watch it again now that you have learned more about genetics and natural selection.

You should read these notes before you watch the programme

This programme broadens the discussion about the inherited disease, sickle-cell disease, in Section 13.3.2 of the book, by putting it into a social context. As well as covering the biological cause of sickle-cell disease and its link with malaria, it also considers the social aspects of how the disease affects the lives of the people who have it and how different communities, in the USA and East Africa, are tackling the care of affected individuals. In addition, the programme reinforces the evolutionary significance of the disease.

You will find it helpful to review the TV programme 'A formidable foe' (Block 4) before viewing this programme. That programme described the life history of the protoctist parasite, *Plasmodium falciparum*, which causes malaria. This has two hosts, mosquito and human, and is transferred between them by the mosquito feeding on the blood of humans. Removing the mosquito would annihilate the protoctist. The reproduction of the mosquito is so successful, however, that it has proved impossible to eradicate, particularly in the tropics of Africa and southern Asia (see Figure 13.6a in the book). Given the long history of malaria and the fact that it is the most prevalent of all serious diseases, it is hardly surprising that humans have evolved mechanisms to 'strike back'.

These are the questions that you should focus on whilst watching the programme.

Question 1 Did the sickle-cell mutation arise in order to combat malaria?

Question 2 How is the high frequency of the *Hb^s* allele maintained when in the homozygous state it leads to a lethal disease which historically caused death in childhood?

Question 3 In the USA, the sickle-cell allele is largely found in populations of African origin. Why is the frequency of the allele much lower in this population than in the population of tropical Africa, even though they have the same genetic origin?

Question 4 What is the term used for a genetic polymorphism in which the heterozygote has a greater fitness than either homozygote, and how is it maintained in the case of sickle-cell disease?

Activity 13.4 Sickle-cell disease: an integrative account

(The estimated time for this activity is at least 1½ hours, or 1 hour if you carry out a suggested shorter alternative)

This activity will help consolidate your understanding of heterozygous advantage and natural selection, and how they affect allele frequencies. In addition, is the sixth and last activity in the block designed to improve your skill at answering assignment questions.

This activity requires you to plan and write a longer account (approximately 600 words) which.

- integrates information from more than one place (book and TV)
- is written for a specific audience; this will determine what science information needs to be included and in how much detail, as well as the style of writing that is appropriate.

We are aware that writing this account in full will be time-consuming, so we suggest (below) both a long and a shorter version of the activity.

Assume that you are invited to write an account about sickle-cell disease for some trainee health visitors working in Manchester. A number of their patients are children with this disease, and the parents of these children all emigrated from central Africa about 30 years ago. The trainee health visitors are biologically literate but want to understand two aspects of the disease: *the origin of sickle-cell disease* and *why this disease is prevalent in this group of people living in Manchester*. The trainee health visitors don't know that the disease is genetically determined but understand the concept of genetics and you can assume they know the following terms: homozygous heterozygous, dominant recessive, allele/mutation and that they are familiar with mating diagrams. They are also familiar with the symptoms of the disease as it is manifest in individuals — both sickle-cell disease and sickle-cell trait and the sickling of red blood cells

We suggest that you tackle this activity as follows:

(a) Start by thinking about the kind of writing required for this particular audience; you will find it helpful to read *SGSG* Chapter 9, Section 2.

(b) A long scientific account, or 'essay', will benefit from planning, and to help you with this we recommend you read *SGSG* Chapter 9, Sections 5.3 and 5.4. Then draw up a plan: make brief notes of what you will include in an *introduction*, select the points that you would include in the *main body* of the account and put them in the order in which you would present them, and plan what to include in the *conclusion*. Also, decide what diagrams you will include.

(c) Having completed your plan, you are ready to write the account, and here we suggest two options.

If you need to practise your writing skills and have the time available. write the complete account, including the introduction, main body and conclusion.

If you are short of time: write the introductory paragraph of the account in full, write a sentence about what is to go in each paragraph in the main body of the account, and then write the conclusion in full. Indicate the diagrams that you would include and where these might be positioned in the account.

After completing either version of part (c), compare your account with an example of a full account in the comments on this activity.

Activity 14.1 Galapagos: adaptation and evolution on islands (Parts 2 and 3)

(The allocated time for this activity is 2 hours.)

You studied Part 1 (*Adaptation*) of 'Galapagos: adaptation and evolution on islands' in Block 4 and learned about adaptation in various Galapagos species. This DVD-multimedia activity requires you to study Parts 2 and 3 of 'Galapagos', which are entitled *Evolution in Real Time* and *Species and Speciation*, respectively. You will investigate variation, natural selection and the evolution of new species in the Galapagos Islands, looking in particular at the various species of Darwin's finch. Before you start, you may wish to remind yourself of the key points in Part 1 *Adaptation* by running through this part again, or by reading the summary screen or the comments on Activity 9.1 in the Study File for Block 4.

Evolution in Real Time and *Species and Speciation* build on a number of concepts you have met before, the most recent being the Red Queen effect (Block 9, Section 14.2), whereby organisms continually have to adapt to new conditions created by a changing environment and changing interactions with other species. You will revise how natural selection is not the same thing as evolution — how, under some circumstances, natural selection *maintains* variation (as shown by the peppered moth, Block 9, Section 13.3.1).

In *Evolution in Real Time*, you will see how subtle differences in a continuously varying character (Block 9, Section 9.5) can mean the difference between life and death for a Darwin's finch when the environment changes or when competition with another species intensifies, with the result that evolutionary change can take place in only a few generations.

In *Species and Speciation*, you will see how populations that become separated on different islands can evolve into separate species if natural selection acts in a different way in each population (e.g. because the environment on each island is different, or competing species are different) and how both genetic drift and the founder effect (both described in Block 4, Section 10.3) can also contribute to this speciation process.

Additional terms used in this activity which are not in the glossary

You are not expected to be able to explain these terms.

emigration The movement of individuals out of a population.

endemic Term describing organisms that are found only in a single geographic area. A species or subspecies can be endemic to a large area such as a continent, or to a small area such as a single island, or to something in between such as a group of islands.

immigration The movement of individuals into a population.

mericarp The part of a fruit containing one or more seeds.

(NB the words that are underlined in the definitions above appear in the *Course Glossary*.)

'Galapagos: adaptation and evolution on islands' is on Block 4 DVD. You should study Parts 2 and 3 now.

Activity 15.1 (a) Reviewing your study of Block 9: learning to be a good judge; (b) Reviewing your revision

(The estimated time for this activity is 40 minutes.)

(a) Reviewing your study of Block 9: learning to be a good judge

A number of activities in this block focused on improving your answers to assignment questions, and there were two main aspects to this. The first aspect was making a critical assessment of answers, in some cases by using a marking scheme. The second was writing accounts of different lengths. In this activity you will follow up each of these aspects

(i) Assessing your own work

Look back at Activities 8.1, 10.1 and 10.2, and think about the criteria used in these activities for assessing the written answers. Then write down a list of criteria by which you will judge your written answers from now on. Such a list will be particularly useful when answering questions in assignments.

(ii) Writing long scientific accounts

Some of the remaining TMAs for the course and the ECA will require you to produce some longer pieces of scientific writing, so it would be useful to reflect on your experience of producing long accounts.

Think back to the last occasion when you produced a long scientific account. This may have been writing an answer to Activity 13.4, or to another activity or to a recent TMA question. What processes did you go through, from reading the question to producing the final version of the answer? Write down the sequence of steps that you followed. (For example, did you begin by rereading the relevant text? Did you produce a plan? Did you write out your answer organized into paragraphs, and then reorder it into a more coherent sequence or did you plan the order carefully and stick to it?)

Now think about the sequence of steps that you have written down. Are there redundant steps, or missing steps? Can you think of a more effective order of doing things? What advice can you give yourself about tackling your next major writing task? You may need to consider advice that your tutor has given you on an earlier TMA.

(b) Reviewing your revision

Revision has been a major theme of Block 9. In particular you have:

- revised material from earlier blocks (predominantly Blocks 4 and 8) to help you in your study of Block 9;
- carried out a number of revision activities on material within this block,
- summarized material from Block 9 in various ways — such as flow diagrams, tables, lists, written paragraphs — which will be useful to you for revision in the future.

Now is a good time to think in general terms about how you revise. The ability to revise effectively will prove a very valuable skill when you study courses that have end-of-course examinations

(i) Look back at the revision activities in Block 9, i.e. those that fall into the first and second categories described above, and make a list of the *ways* in which we have asked you to revise. For example, in Activity 2.1 we asked you to complete a table, whereas in Activity 13.2, we asked you questions to test your understanding of an earlier part of the block. Then make a second list of the ways in which you have summarized a number of pages.

(ii) For each of the methods of revision, and for each of the methods of summarizing that you listed in part (a), make a note of how helpful/unhelpful you thought it was. Which methods would you use if you had to revise for an examination?

Further advice about revision is given in the comments on this activity

Comments on activities

Activity 1.1

This activity introduced you to biological fieldwork and allowed you to study the life cycle of the holly leaf miner and its parasites. You identified some of the mortality factors that operate at different stages of the miner's life cycle, and calculated the relative magnitude of each factor. This allowed you to identify the key mortality factor (the factor that influences the size of a population more than any other factor) and a regulating mortality factor (a factor that causes greater than average mortality when population numbers are high, and lower than average mortality when population numbers are small, i.e. it acts in density dependent way, dampening down changes in population numbers). It also showed you how knowledge about various mortality factors can be used when devising means for the biological control of pest species.

Activity 2.1

The completed version of Table 2.1.1 is given in Table 2.1.2

Revising and integrating information

You may have found that you had to refer back to Block 4 in order to complete the table. Revising and integrating knowledge from earlier in the course is a feature of this block. If you generally only carry the current block around with you, then you need to plan ahead and make sure you have the earlier blocks with you when you need them. To help you with this, the main back references are

- Section 2, on the structure of cells, builds on the information in Section 3.1 of Block 4.
- Section 3, on the range of molecules that make up cells, builds on information in Sections 12–16 of Block 8
- Sections 4 and 5, on chemical reactions and the production of energy within cells, build on information in Section 2.3 of Block 4, and Section 6 of Block 8.

- Section 8, on genes and the transmission of characters from one generation to the next, builds on Sections 3.3 and 6.2 of Block 4.
- Sections 13 and 14, on evolution, integrate information from Sections 8, 9 and 12 of this block and build on concepts introduced in Sections 9–11 of Block 4.

Other components of the block also integrate knowledge from sources within this block and other blocks.

- DVD-multimedia Activity 7.1, 'Cells and energy', reviews and integrates information from Sections 2–6 of this block
- DVD-multimedia Activity 8.4, 'Mitosis, meiosis and recombination', revises and integrates information from Section 8 of this block and Sections 3.3 and 6.2 of Block 4.
- DVD-video Activity 11.4, 'Information flow in cells', reviews material in Sections 3, 10 and 11 of this block.
- Activity 13.3, TV programme 'Sickle-cell disease: a lethal advantage', integrates information within this block and builds on the TV programme associated with Block 4, 'A formidable foe'
- DVD-multimedia Activity 14.1, 'Galapagos: adaptation and evolution on islands (Parts 2 and 3)', builds on information in Sections 8, 9, 13 and 14 of this block, and on Sections 9–11 and Part 1 of this activity in Block 4.

Reworking and extending earlier knowledge is an important way to consolidate your understanding. When you come to revise ideas from earlier in the course, you will not want to have pages and pages of notes; gathering together important information in a table, as you did here, or as a condensed paragraph, a bullet point list or a spray diagram, is a valuable way to home in on the core of the information you need. Also, working like this makes it easier to remember the concepts. This is partly because you have reworked them actively, and partly because you have assembled them in a form in which you can remember them more easily.

Table 2.1.2 Completed version of Table 2.1.1, Characteristics of the domains and kingdoms.

Domain/kingdom	Unicellular or multicellular	Eukaryotes or prokaryotes	Autotrophs or heterotrophs
domain Archaea	unicellular	prokaryotes	autotrophs and heterotrophs ¹
domain Bacteria	unicellular ¹	prokaryotes	autotrophs and heterotrophs ³
kingdom Animalia	multicellular	eukaryotes	heterotrophs
kingdom Fungi	multicellular ²	eukaryotes	heterotrophs
kingdom Plantae	multicellular ²	eukaryotes	autotrophs
kingdom Protocista	unicellular ¹	eukaryotes	autotrophs and heterotrophs ³

¹ Most bacteria and most protocists are unicellular, but a few species of both are multicellular.

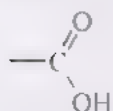
² Most fungi are multicellular, but a few species are unicellular, notably the yeasts. Most plants are multicellular.

Notice that the three domains/kingdoms comprising the unicellular organisms include mixtures of heterotrophs and autotrophs. Most species within these groups are either heterotrophic or autotrophic. (A small number of species, however, can be either heterotrophic or autotrophic, depending on the prevailing conditions, notably the availability of organic carbon.)

Activity 3.1

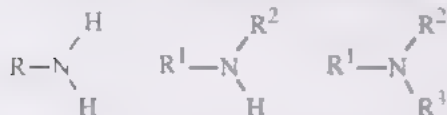
Our answers are as follows:

A *carboxylic acid* is an organic compound containing the carboxyl group:



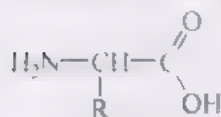
For example, propionic acid, $\text{CH}_3\text{CH}_2\text{COOH}$ is a carboxylic acid.

An *amine* is an organic compound containing nitrogen:



For example, methylamine, CH_3NH_2 is an amine. Amines are basic, so they react with acids.

An *amino acid* is an organic compound with an amine group and a carboxylic acid group:



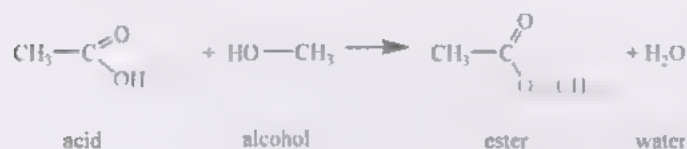
Note that the amine group, —NH_2 , is generally called an *amino* group in biology, and we will use this name for the group in Block 9.

A *catalyst* changes the rate at which a chemical reaction occurs, but is itself unchanged at the end of the reaction.

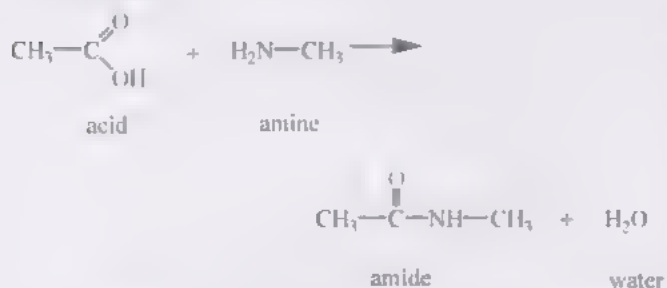
An *enzyme* is an organic catalyst produced by living cells; e.g. trypsin, which catalyses the breakdown of food protein in the gut

In a *condensation reaction* two functional groups from two separate monomers react with each other; a covalent bond is formed and a molecule of water is eliminated

Example 1.

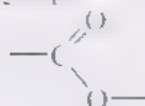


Example 2

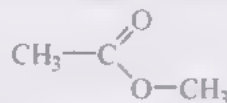


A *covalent bond* is a strong bond in which the electrons are shared by the atoms involved in the bond; for example, CH_4 has four covalent bonds, one between carbon and each hydrogen.

An *ester* is an organic compound containing the ester group.



For example, methyl acetate.



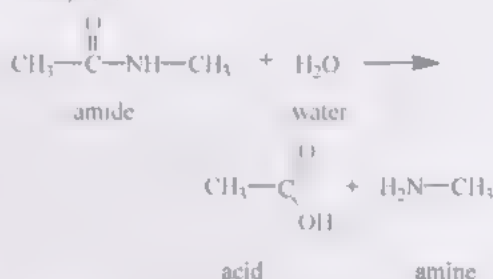
which is formed in the condensation reaction between an acid (acetic acid) and an alcohol (methanol).

Hydrolysis means 'splitting with water'. It is the opposite of condensation, and involves breaking a covalent bond in a reaction in which water is consumed.

Example 1

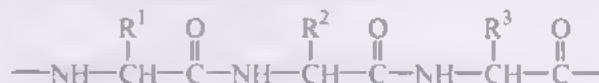


Example 2



A *monomer* is a small molecule from which polymers are built up. For example, amino acids are monomers of proteins. The monomers must have two functional groups which react to form strong covalent bonds. For example, all amino acids have an amino group at one end and a carboxylic acid group at the other, as in glycine: $\text{H}_2\text{N—CH}_2\text{—COOH}$.

A *polymer* is a large molecule built by many small molecules reacting together. Most biopolymers are a result of condensation reactions; e.g. three amino acids condense to form part of a protein:



Note that the amide bonds formed when amino acids condense in this way are generally called *peptide bonds*.

It is worth making a general point about this activity. Like the earlier revision activity (Activity 2.1), the idea here has been to reduce a large amount of information to a manageable quantity, with the key concepts standing out, ready to be used in Block 9. The actual examples you have chosen will probably be different, but they should be meaningful to you. When you want to recall something, you may find that you can remember either an example, from which you can construct the description or definition for yourself, or you can remember the description. Either way will help you to interpret further examples, and to make sense of additional related information

Activity 3.2

(a) The following are possible interactions between the R groups

ionic interactions: Asp (aspartate) and Lys (lysine).

hydrogen bonds: Ser (serine) and Thr (threonine); Asp and Ser; Asp and Thr; Lys and Ser; Lys and Thr.

hydrophobic interactions: Ala (alanine) and Val (valine); Ala and Ile (isoleucine); Ala and Phe (phenylalanine); Val and Ile; Val and Phe; Ile and Phe

(b) Hydrophobic groups (R groups of Ala, Val, Ile and Phe) are 'water-fearing' and hence are found towards the interior of the molecule. Many hydrophilic groups (R groups of Asp, Lys, Ser and Thr) will also find themselves in the interior when the polypeptide chain folds up, where they will interact with each other (as in (a) above). However, where hydrophilic groups occur on the surface of the protein they will interact with water molecules.

Activity 3.3

Here is one possible answer.

Sam

I've tried to explain by making sure that you understand the terms we are working with. (The figure numbers refer to the ones in the book)

The *primary structure* of a protein or polypeptide is its sequence of amino acids (Figure 3.1). These are linked together by peptide bonds (Figure 3.19) between the amino group of one amino acid and the carboxylic acid group of the next amino acid, forming a chain. There are 20 different amino acids and these can be joined up in a huge number of different sequences, with some amino acids repeated and some not present at all in a particular string. What's important is that each sequence is unique to a specific protein, such as trypsin that we met in Block 8.

A globular protein does not exist as an extended string of amino acids: it folds up on itself to give a three-dimensional shape. This is what is meant by the *higher-order structure*. Figure 3.5 shows what a globular protein looks like, and how this overall shape relates to the polypeptide chain.

In addition to the amino group and the carboxylic acid group, amino acids all have an R group — a different one for each of the 20 different amino acids (Table 3.2). The R groups stick out from the polypeptide chain and it is these that are responsible for forming the higher-order structure of the protein, because they interact with each other. Some R groups form hydrophobic interactions, some form hydrogen bonds and yet others form ionic interactions with each other. A protein folds up so that the maximum number of weak bonds are formed between pairs of similar kinds of R groups. As long as the sequence of amino acids is the same, the protein will always fold up in the same way and hence have the same higher-order structure.

I hope this explanation helps! (309 words)

What's important here is that the student has explained the scientific terms in the question. This is a good basic principle to remember when answering questions in assignments; you should assume that your tutor does not know the meaning of these terms. It is also important that you explain the science, and one way of doing this

is to assume that you are writing your answers for a fellow student who doesn't understand'

Activity 3.4

There are no comments on this activity.

Activity 4.1

(a) (i) Increasing the concentration of the reactants increases the probability of reactant molecules encountering each other.

(ii) Increasing the temperature ensures that more encounters between molecules have sufficient energy to overcome the energy barrier.

(iii) A catalyst lowers the energy barrier of the reaction

(b) (i) The reaction shown in Equation 4.1.1 is an oxidation reaction, because the proportion of oxygen atoms increases and the proportion of hydrogen atoms decreases (see Section 14.2.2, Block 8). If you simply answered 'oxidation', then you have not answered the question adequately, since it asked you to *explain* the type of reaction, i.e. to give reason(s) why it is this type of reaction

(ii) The reverse reaction is a reduction reaction, because the proportion of hydrogen increases and the proportion of oxygen decreases.

Activity 5.1

After Section 5.1

We added to our summary diagram the locations in the cell of each of the four stages of glucose oxidation: *cytosol* is where glycolysis occurs, *mitochondrial matrix* is where the link reaction and the TCA cycle occur, and *inner mitochondrial membrane* is where electron transport coupled to oxidative phosphorylation occur. We also drew a dashed line separating Stage 1 from Stages 2-4, since the first stage happens in the cytosol and the last three occur in the mitochondria

After Section 5.2

We added a number of detailed points to help our understanding of glycolysis: *6C-bisphosphate*; *ATP × 2* (used to phosphorylate glucose); *3C-bisphosphate × 2*; *× 2* beside *NAD.2H*; *× 4* beside *ATP*; and *× 2* beside *pyruvate*

After Section 5.3

We added *× 2* at the side of *CO₂*, *NAD.2H* and *acetyl CoA* produced in the link reaction.

After Section 5.4

We wrote *× 2* inside the TCA cycle to remind us that the cycle turns twice for every molecule of glucose oxidized, then showed where in the cycle each molecule of *NAD.2H* (and *FAD.2H*) is produced, and we also added the term *useful carbon intermediates*.

After Section 5.5

We added the following to Stage 4 of our summary diagram: *ETC*, *H → e⁻ + H⁺*, *proton pumping*, *ATP synthase*. In addition, we wrote *substrate-level phosphorylation* alongside the *ATP* produced during both glycolysis and the TCA cycle. Finally, we added the reactions of *anaerobic respiration* from *pyruvate*:

the production of *lactate* + *NAD*, and the production of *alcohol*, CO_2 + *NAD*.

Now compare your completed diagram with ours (Figure 5.1.2).

We selected only the essential information to add to our summary diagram, and so you may have added further details to your own. For example, you may have chosen to show that the coenzyme A (CoA) is recycled and included the reactions occurring between the ETC, proton pumps and ATP synthase. What is important, if your diagram is to be useful for revision purposes, is that it is clear and easy to follow. The pathway of glucose oxidation is complicated and difficult to 'visualize' as text. Your summary diagram should make the pathway easier to understand, because it shows how the reactions involved relate to each other

You will also be able to review your understanding of glucose oxidation in the DVD-multimedia activity, 'Cells and energy' (Activity 7.1).

Activity 5.2

Check your completed flow diagram with ours in Figure 5.2.1 (*overleaf*). You might have drawn yours differently. For example, you might have drawn the reactions that occur in the TCA cycle as a cycle; we chose not to do this because we wanted to emphasize that most of the energy from the 2C acetyl group is transferred during this cycle to reduced coenzymes, particularly $\text{NAD} \cdot 2\text{H}$, and a small amount is harvested to produce ATP by means of substrate-level phosphorylation. The energy stored in the reduced coenzymes is released during Stage 4 of glucose oxidation via a number of steps, eventually being transferred to ATP.

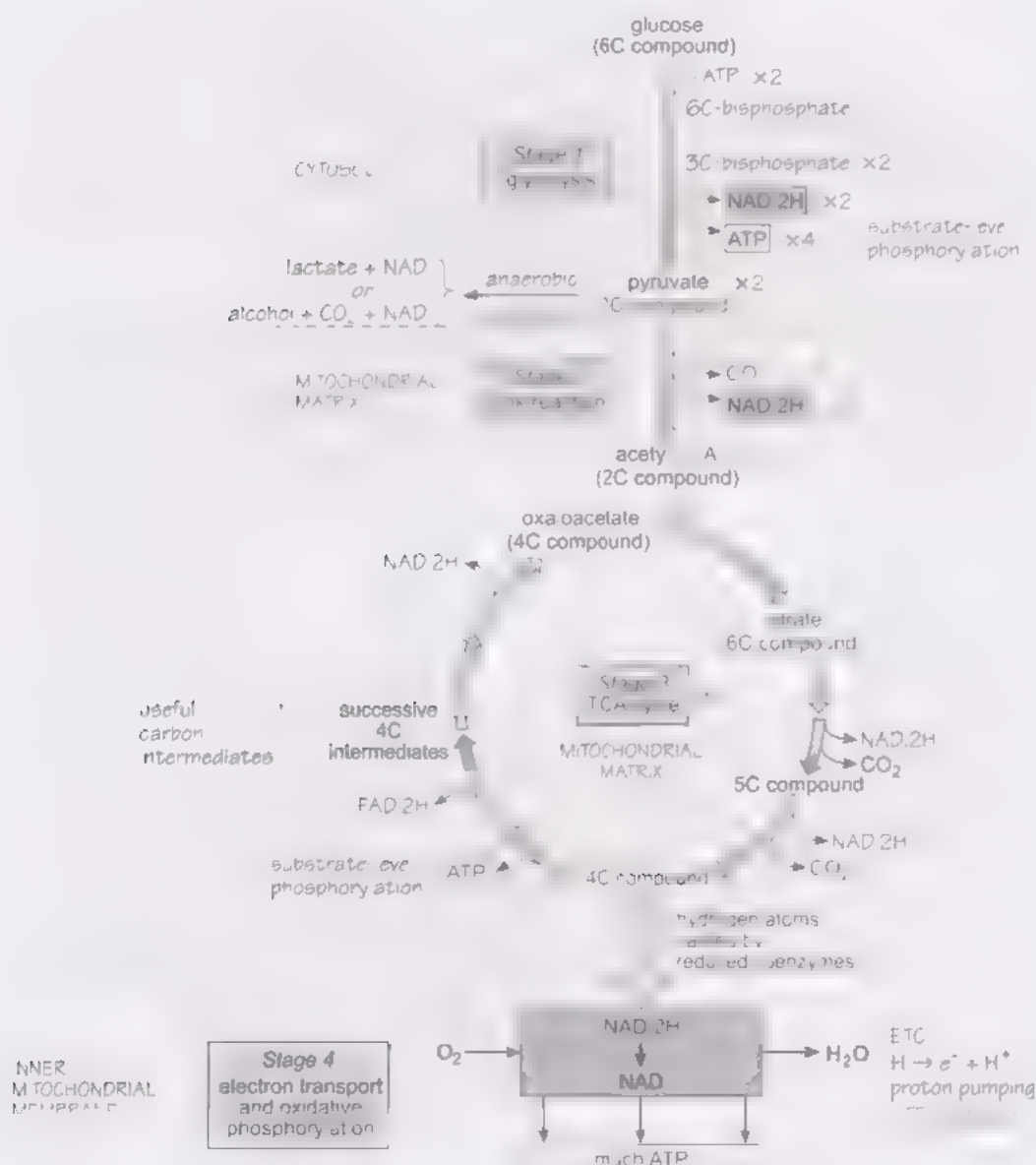


Figure 5.1.2 Completed version of Figure 5.1.1. A summary of glucose oxidation

What is important is that your diagram shows all the steps involved in the transfer of energy to ATP, and that it makes sense to you. This is quite a difficult activity and if you got most of the steps then you have followed the text very well. Drawing this flow diagram should have prompted you to think more carefully about the sequence of events occurring in the mitochondria. Remember that flow diagrams like this summarize a considerable number of pages of text and so are useful revision aids

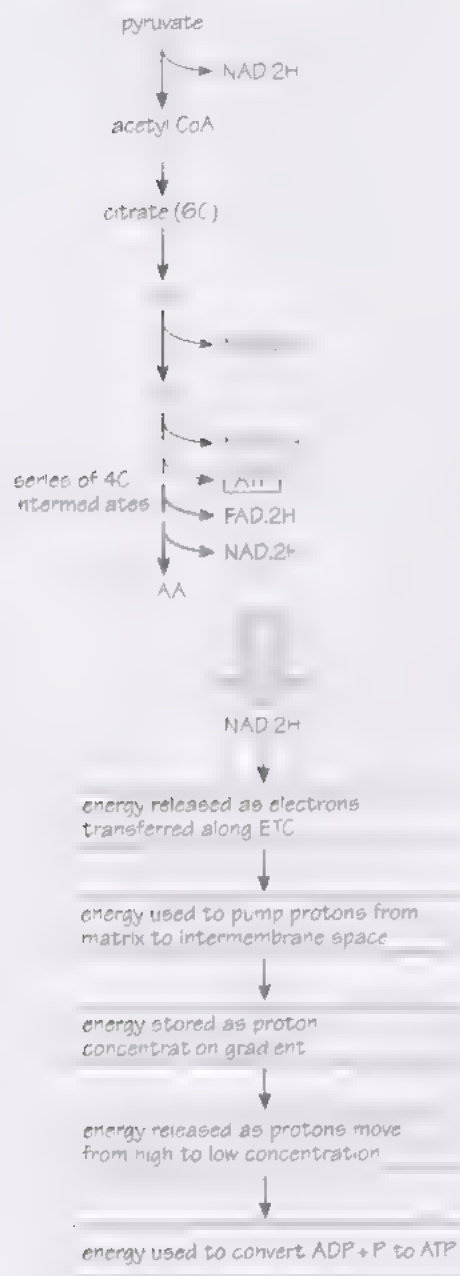


Figure 5.2.1 Flow diagram summarizing the transfer of energy stored in pyruvate to ATP in the mitochondria.

Activity 7.1

In this activity you reviewed the structure and function of organelles, concentrating on the differences between prokaryote cells, animal cells and plant cells (covered in Section 2.1 of the book). You have followed the pathway of glucose oxidation and seen where each of the steps occurs within the cell and how these steps relate to each other.

The process of photosynthesis, which includes photo-phosphorylation, was compared with that of glucose oxidation, which includes oxidative phosphorylation.

Activity 8.1

Compare the marks that you awarded with those awarded by an S103 tutor.

The student has made several scientific errors

The terms 'mitosis' and 'meiosis' have been consistently reversed, so the student would not get the marks for either of these. 'Autosome' and 'sex chromosome' are also wrongly used. (Note that an autosome is a chromosome other than a sex chromosome. Autosomes are present as matching pairs, but this is not always true for sex chromosomes. In human females the sex chromosomes match, but in males they do not.) The words 'ovum' and 'fertilization' are completely missing. 'Gamete' and 'zygote' are used correctly but not explained well. The remaining six terms are used correctly. *Awarded 7/14 for correct use of terms*

The diagram clearly illustrates the variation of chromosome number throughout the life cycle. *Awarded 2/2*

It is a good diagram (apart from the confusion of mitosis and meiosis, for which the student has already been penalized) but it does not have a title. *Awarded 3/4 for diagram.*

The written style is clear, concise and coherent. The answer is well within the word limit. The only repetition is the sentence: 'Haploid cells contain one set of chromosomes and diploid cells contain two sets'. *Awarded 4/5 for quality of writing*

Overall mark awarded: 16/25.

Do you think the mark that you awarded and/or the tutor awarded were a fair assessment of the quality of the work?

A corrected version of the student's written answer is given below, with corrected words and additions italicized, and with repetitions (to be deleted) underlined.

Haploid cells contain one set of chromosomes and diploid cells contain two sets, with each chromosome (usually) having a morphologically identical partner. *Some species, including humans, have sex chromosomes, usually called X and Y chromosomes. These differ from the remaining chromosomes — which are collectively called autosomes — in that they do not form a matching pair.* For part of the cell cycle individual chromosomes are single-stranded but by the beginning of *mitosis* they are double-stranded. Each strand is called a chromatid and the two strands are held together at the centromere. Haploid cells contain one set of chromosomes and diploid cells contain two sets.

Adult animals and plants are diploid, with very few exceptions. No species of eukaryote that reproduces sexually is composed entirely of haploid or entirely of diploid cells at all stages of its life cycle. The alternation of these two types of cells within the life cycles of organisms is shown in the diagram.

The production of haploid gametes is brought about by the process called *meiosis*. *A gamete is a haploid cell capable of fusing with another cell at fertilization. Thus the diploid number of chromosomes is restored at fertilization. A fertilized ovum is called a*

zygote. The zygote divides by means of *mitosis* to produce an adult organism. *Mitosis* occurs as a series of stages, named prophase, metaphase, anaphase and telophase. Each cell of the adult, other than the reproductive cells, contains identical copies of the genetic material. (229 words)

Figure 8.1.2 is the correct version of the accompanying student's diagram.

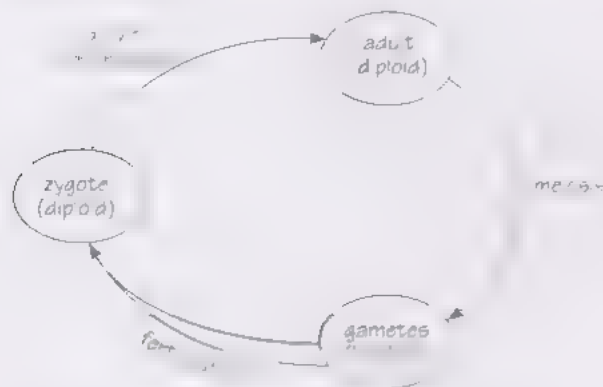


Figure 8.1.2 Corrected version of student's diagram for Activity 8.1

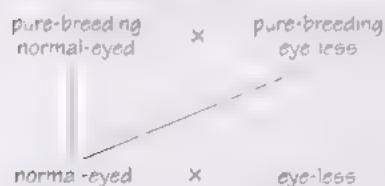
This was a difficult activity, and will have given you some insight into what your tutor has to do to mark your TMA! But it should also help you to look critically at your own TMA answers, and to improve them, before you send them to your tutor.

Activity 8.2

We solved the problem by working through each step in the guidelines in turn:

1 Pure-breeding parents, by definition, must be homozygous, since they breed true; since the two varieties have contrasting characters, they are homozygous for different alleles of the gene for eye shape.

2 We drew out a mating diagram using the information given in the question:



3 Next we assigned letters to alleles of the gene for eye shape. Since normal shape appears in the F_1 generation we deduced that normal shape is dominant to eye-less; we used EE for normal-eyed flies and ee for eye-less, but you may have chosen a different letter.

4 We then drew the mating diagram as shown in Figure 8.2.1. (The normal-eyed F_1 fly must be heterozygous (Ee) since it is the offspring of EE and ee pure-breeding parents. All eye-less flies must be ee because this phenotype is recessive.)

5 The phenotypes of the offspring of the second cross are (Ee) normal-eyed (since E is dominant to e) and (ee) eye-less

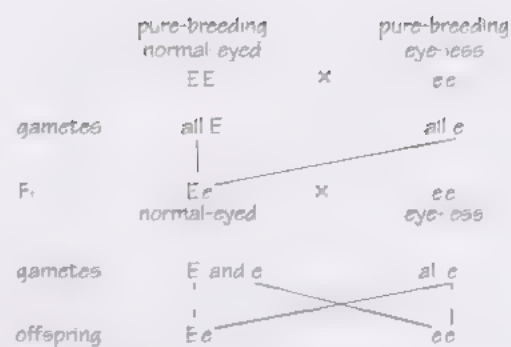


Figure 8.2.1 Completed mating diagram for Activity 8.2

6 The ratio of the two genotypes of the offspring of the second cross is $1 Ee : 1 ee$, and the ratio of the two phenotypes is one normal-eyed (Ee) : one eye-less (ee).

7 The results appear consistent with what we know of genetics, and the ratio is a familiar genetic ratio.

You can use the guidelines again when tackling genetics problems later in the block

Activity 8.3

(a) There are 134 purple and 42 white grains visible (you may have counted slightly different numbers depending on whether or not you included part grains that are visible). This gives a ratio of 134:42, which simplifies to 3.19:1.

(b) The numbers of purple and white grains that you counted will be much smaller than the values in Table 8.2, since you counted grains on only part of a cob. However, for each cob in Table 8.2 the ratio of purple to white grains, to the nearest whole number, is 3:1, although all the cobs show a slight deviation from this. Your ratio will show a deviation from 3:1, but the deviation is likely to be within the range covered by the ratios in Table 8.2

(c) The deviation from a 3:1 ratio is due to chance events. Possibly the number of G -bearing ovules on the cob was not equal to the number of g -bearing ovules and/or possibly the numbers of G -bearing pollen and g -bearing pollen that succeeded in fertilizing the ovules were not equal. The total number of grains counted was relatively small, hence the chance of a deviation from the expected ratio is high

(d) There are 134 purple and 42 white grains visible, giving a total of 176.

Thus the number of white grains as a fraction of the total number is $\frac{42}{176}$ which is $\frac{1}{4.19}$, i.e. approximately $\frac{1}{4}$.

(e) There are four possible outcomes for a cross between two maize plants that are heterozygous for grain colour. Two of these outcomes give the Gg genotype, one gives GG and one gives gg , so the probability that an F_2 maize grain has the genotype gg is $\frac{1}{4}$. The value that we calculated in (d) is in good agreement with the expected value of $\frac{1}{4}$, although it is not exactly the same because of chance variation

(f) In part (a) we discovered that the ratio of purple to white grains was approximately 3:1. In part (d) we

found that the fraction of white grains was approximately $\frac{1}{4}$ of the total. The difference in numbers here is a frequent source of confusion; you may wonder why the fraction is not $\frac{1}{3}$? When dealing with ratios and fractions it is important to be clear in your own mind what you are calculating the ratio or fraction of. On this occasion

3 : 1 = number of purple grains : number of white grains

and

$$\frac{1}{4} = \frac{\text{number of white grains}}{\text{total number of grains}}$$

The total number of grains clearly includes both the purple grains and the white grains, so if there were $3x$ purple grains and x white grains — a ratio of $3x : x$, or $3 : 1$ — then the fraction of the total number of grains that were white would be

$$\frac{x}{3x + x} = \frac{x}{4x} = \frac{1}{4}$$

So the reason for the difference between the 3 in the ratio and the 4 in the fraction is simply that in the ratio we are comparing the number of white grains with the number of purple grains, whereas in the fraction we are comparing the number of white grains with the *total* number of grains.

Let's take another example from a different area of science. The methane molecule, CH_4 , contains one C atom and four H atoms, so the ratio of the numbers of atoms is 1 C : 4 H. But if you ask what fraction of the atoms in the methane molecule are carbon, then the answer is

$$\frac{1}{1 + 4} = \frac{1}{5}$$

So when you are dealing with fractions and ratios it is important to be clear about what you are comparing. Ask yourself: 'what am I calculating the ratio of?' or 'what am I calculating the fraction of?'.

Activity 8.4

(The terms emboldened in this summary were introduced and explained in the DVD-multimedia activity and you will find them in the *Course Glossary*. These are important terms, which we expect you to be able to explain and to use correctly.)

In mitosis the nucleus divides to produce two new nuclei, which are genetically identical to each other and to that of the original parent cell. The individual chromosomes, each consisting of two chromatids, shorten; fibres of the **spindle** become attached to the centromeres of each chromosome; these threads exert a tension on the chromosomes so that the chromosomes become aligned along the *equator* of the cell. The two chromatids of each chromosome then separate to opposite *spindle poles*, and nuclear membranes form around each group of chromosomes prior to cell division. Mitosis was first discussed in Block 4, and additional details were included in this DVD-multimedia activity.

Unlike mitosis, meiosis consists of *two* successive nuclear divisions. During division I, homologous pairs

of chromosomes, each chromosome consisting of a pair of chromatids, are aligned along the equator and each homologue separates (or *segregates*) to opposite ends of the cell. The arrangement of chromosome pairs and the separation of members of one pair of homologous chromosomes, during division I, are independent of that of any other chromosome pair. The technical term for pairs of chromosomes assorting themselves independently in this way is **independent assortment**. The cell divides to give two new nuclei, each with half the original number of chromosomes. Both cells enter division II. Individual chromosomes align along the equator and the two chromatids of each chromosome separate to opposite ends of the cell, as in mitosis. Each cell then divides to give two haploid cells, giving a total of four haploid cells.

During prophase I, homologous chromosomes pair together in close juxtaposition to form **bivalents**, and the chromatids of an homologous pair can exchange material in the process called **crossing over**.

The behaviour of copies of genes, or alleles of a gene, follows the behaviour of chromosomes; they also separate (segregate) at meiosis. There are two separate situations involving the inheritance of more than one pair of contrasting characters. Where the genes for different pairs of characters are situated on *different* chromosomes, then the chromosomes and genes assort at random or *assort independently* of one another during meiosis. In the second situation, where genes for different pairs of characters are situated on the *same* pair of homologous chromosomes, the genes are said to be **linked** together and do not assort independently of each other. Linked genes are inherited together except where linkage is broken by crossing over.

Both independent assortment and crossing over lead to the **recombination** (new combinations) of genes and alleles. Both these processes can be correlated with chromosome behaviour at meiosis.

The probability that crossing over will occur between two loci on the same pair of homologous chromosomes during any one meiosis increases with increasing map distance. The frequency of crossing-over can be used to draw up **genetic (linkage) maps**, which show the order of genes along each chromosome.

Activity 9.1

Before beginning Section 9.1

Table 9.1.1 is a list of sources of phenotypic variation that were discussed in Section 8

After completing Section 9.6

The sources of phenotypic variation discussed in Section 9 are listed in Table 9.1.2.

You don't need to be able to recall the details presented in Tables 9.1.1 and 9.1.2, but you do need to be able to explain each of these sources of phenotypic variation. The most significant sources of genetic variation for the process of evolution are revisited in Section 13.2

As a result of this activity you now have a summary which you can use for reference and revision purposes, both later in this block and at the end of the course. It is worth making a few general points about this activity.

Table 9.1.1 Sources of phenotypic variation introduced in Section 8.

Source of phenotypic variation	Notes and examples
alternative alleles which segregate to different gametes	different phenotypes, e.g. purple and white grains of maize
recombination of alleles	(i) independent assortment of genes on separate homologous chromosomes (see DVD-multimedia Activity 8.4, Section 9, <i>Alleles on two pairs of chromosomes</i> genes <i>Aa</i> and <i>Bb</i>); (ii) crossing over between linked genes (see DVD-multimedia Activity 8.4, Section 11, <i>Crossing over</i> ; genes <i>Aa</i> and <i>Dd</i>)

Table 9.1.2 Sources of phenotypic variation introduced in Section 9.

Source of phenotypic variation	Notes and examples
sex-linked genes (Section 9.1)	genes with no counterpart on the Y chromosome in males, e.g. white eyes in <i>Drosophila</i>
multiple alleles (Section 9.2)	different pair-wise combinations of alleles of the same gene, e.g. ABO blood groups in humans
many genes may affect one character (Section 9.3)	gene interaction, e.g. coat colour in cats
one gene may affect more than one character (Section 9.3)	more than one distinct phenotypic effect, e.g. vestigial wings in <i>D. melanogaster</i>
environment (Section 9.4)	same genotype but different environment lead to different phenotypes, e.g. temperature affects colour of Siamese cats, diet affects weight in humans
continuous variation (Section 9.5)	a number of genes, each with a small effect, produces quantitative differences, e.g. height in humans, milk yield in cattle
gene mutation (Section 9.6)	change from one allele to another, e.g. haemophilia in humans
chromosome mutation (Section 9.6)	abnormal number of chromosomes, e.g. Down's syndrome

1 You completed half of your summary by reviewing Section 8 and the other half as you read Section 9. You will almost certainly have found it easier to produce the summary as you went along, but will you remember this part of the material so well in a few weeks time? Trying to recall information a day or so *after* reading a section can help you remember it better in the long term. Also, looking back to find out something you've forgotten can help you to remember it better. This is worth bearing in mind as a general revision tip.

2 We have presented our summary as a table. You may have presented yours in a different way and this is perfectly acceptable. Note though that a table sets out the information in a logical way and compresses several pages of text into one, making it useful for revision purposes.

3 Note also that we have included examples (as in Activity 3.1) in order to help recall the sources of phenotypic variation. Thinking of 'real-life' examples is another way of helping you to remember what you have learned

eyed ($r-$). The phenotypic ratio of all red-eyed flies to white-eyed flies would be 3:1, and the overall ratio would be two red-eyed females : one red-eyed male : one white-eyed male.

(c) Males have to inherit only *one* copy of the recessive allele for the phenotype to be shown, whereas females have to inherit *two* copies of the recessive allele, one from each parent, in order for the recessive phenotype to be manifest

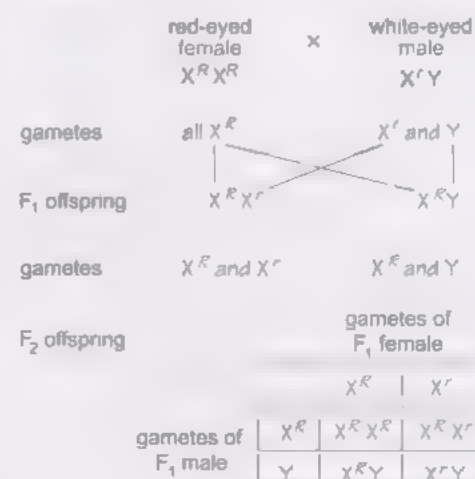


Figure 9.2.2 Completed version of Figure 9.2.1

Activity 9.2

(a) The completed diagram, summarizing Morgan's observations, is shown in Figure 9.2.2. Note that the white-eyed flies are all male (and incidentally they appear every alternate generation).

(b) Half of the F₂ offspring would be female (XX) and half would be male (XY). All the female F₂ offspring are red-eyed, in a 1 RR :1 Rr genotypic ratio. Half of the males would be red-eyed ($R-$; they would have only one copy of the gene) but the other half would be white-

Activity 9.3

(a) Since the genotypes AA and AO produce the same phenotype (A), allele O must be recessive to allele A ; similarly, the genotypes BB and BO have the same phenotype (B), so allele O must be recessive to allele B .

(b) Since the phenotypes A and B are expressed simultaneously in an individual with the genotype AB , neither of the alleles A and B is dominant to the other. This condition is called codominance.

(c) The mating diagram is shown in Figure 9.3.1. The children would have either the A phenotype (genotype AO) or the B phenotype (genotype BO). Thus the children have different phenotypes from either of their parents

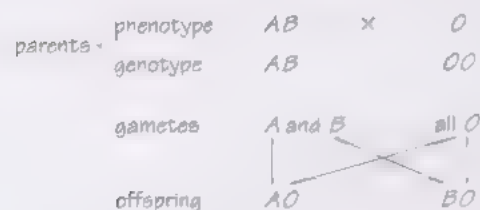


Figure 9.3.1 Mating diagram for Activity 9.3, part (c).

Activity 10.1

You probably found it quite difficult to mark your own answer, though generally marking the scientific content is more straightforward than marking the presentation/writing skills. In addition, most people find it much harder to be critical of their own work in a sensible way than to be critical of other people's, and only you know how well you did! Being critical involves a lot more than saying 'it's hopeless' or 'it's brilliant', you need to be able to take it to bits, looking at different aspects of the whole. We gave you a mark scheme on this occasion to help you to identify the sorts of things that the tutor was looking for. When you write answers to TMAs you do not have the benefit of the mark scheme, but you should be able to work out a lot about what is required from the question. For example, the key point of the question here was the phrase 'features common to the main groups of biopolymers'. This tells you that you must concentrate on, and emphasize, the common features and not just write about each biopolymer in turn, an approach that would involve just regurgitating text from the book. In addition, the recommended word limit gives you a hint of the amount of detail required.

It is worth trying to develop the habit of reviewing your answers and deciding what is good about them and what is bad about them (and making changes where necessary) before sending the TMA to your tutor.

Here is a **review checklist** which you can use, preferably a day or so after drafting each answer so that you come to it afresh:

- Have I answered the question set?
- Have any points been omitted, and is each point covered in sufficient depth?
- Is the material arranged logically, or does the answer need restructuring?
- Have relevant diagrams and formulae been included and have each been referred to in the text?

- Is the meaning clear? (Remember to try reading your answer aloud)
- Are there any repetitions or unnecessary words or phrases?

Here is an answer that contains all the relevant points. It would have been awarded full marks

The following features are common to the three groups of biopolymers. They are all extremely large molecules, composed of large numbers of monomer units: amino acids for proteins, monosaccharides for polysaccharides, and nucleotides for nucleic acids. The monomers are linked together by covalent bonds formed as a result of condensation reactions, with the loss of water. The molecular structure and hence shape of each group of biopolymers is closely related to its particular function. Weak bonds maintain higher-order structure. In polysaccharides, the higher-order structures include single long chains as in cellulose (Figure 1, cellulose), and branched chains as in amylopectin (starch) and glycogen (Figure 2, amylopectin). The higher-order structure of proteins varies from helices wound round each other, as in the fibrous proteins collagen and keratin (Figure 3, collagen), to highly folded complex three-dimensional shapes, as in globular proteins such as enzymes, antibodies, receptor proteins and the oxygen-storing protein myoglobin (Figure 4, myoglobin). (155 words)

Finally, note that this activity has helped you to pull together a considerable amount of information from a number of subsections of Section 3, and to condense it into a paragraph which will be useful for revision purposes if you decide to study biology courses at a higher level.

Activity 10.2

The good and poor points for each answer that we noted are as follows.

Answer 1

1 There is just one error in the science content of Answer 1: DNA replication is semi-conservative not conservative; however, the correct explanation of this type of replication is given.

2 The answer contains most of the relevant points, but it does not outline the structure of DNA, nor explain the term replication. You should include such explanations to make your answer clear to the reader and to show your tutor that you understand the terms. (This was demonstrated in Activity 3.3.)

3 The answer is quite hard to read because there are several errors in the writing

(a) 'On which a new strand is synthesized' is not a sentence because it does not say what 'on which' is referring to. This needs to run on from the previous sentence to read '... each single polynucleotide strand forms the template on which a new strand is synthesized.'

(b) 'DNA polymerase adds nucleotides and the base-pairing rules' needs an extra verb to make sense. We corrected it to read 'DNA polymerase adds nucleotides and the base-pairing rules apply'.

(c) In the penultimate sentence, the word 'synthesized' has been accidentally written as 'synthesizer'. Errors

like this are very easy to make, but you can usually spot them in your own work by reading it carefully — particularly by reading it aloud — before sending it to your tutor.

4 Most importantly, this student has not included a diagram. A diagram was specifically requested so, if this was a TMA question, marks would have been lost for not including one. A diagram would also have made the paragraph easier to understand.

So, Answer 1 illustrates how important it is to take care with your written work: the science content is almost correct; there are just three simple errors in the writing, and the scientific terms in the question have not been explained. The result is that the answer is quite difficult to understand.

Answer 2

1 This contains two scientific errors: DNA replication is semi-conservative, not conservative, and the base-pairing rules are erroneous — G binds to C, and T binds to A.

2 The scientific term 'replication' given in the question is well explained.

3 This answer is rather short, because there are omissions: it makes no mention of DNA polymerase; it does not explain the double-helical structure of DNA nor what semi-conservative replication is (although the diagram does illustrate both of these).

4 A useful diagram is included, and this is referred to in the answer, although it could have been used more. Since the base-pairing rules are shown correctly in the diagram, the error in the paragraph does not necessarily reflect lack of understanding.

General comments

The best points of Answer 1 and Answer 2 have been combined into the summary below. Note that this paragraph condenses two pages of text from the book into about 150 words, so it would be useful for revision. A diagram is included, which is identical with the one presented in Answer 2. This diagram is particularly important in that it summarizes the structure of DNA, how the structure is important for replication, and what semi-conservative replication is.

DNA is a biopolymer of nucleotides. It is composed of two polynucleotide strands interwoven into a double helix, the two strands being joined by hydrogen bonds between complementary bases of each strand (Figure 10.2.2, top). During DNA replication, which is the synthesis of an exact copy of the molecule, the helix unwinds, and each single strand forms the template on which a new strand is synthesized. DNA polymerase adds nucleotides one at a time and the base-pairing rules apply: G binds to C, and T binds to A. The sugar-phosphate backbones of the DNA molecule are formed. Two identical helices are thereby synthesized (Figure 10.2.2, bottom). This is semi-conservative replication, because each new double helix contains one polynucleotide strand from the original molecule and one newly synthesized strand. (147 words)

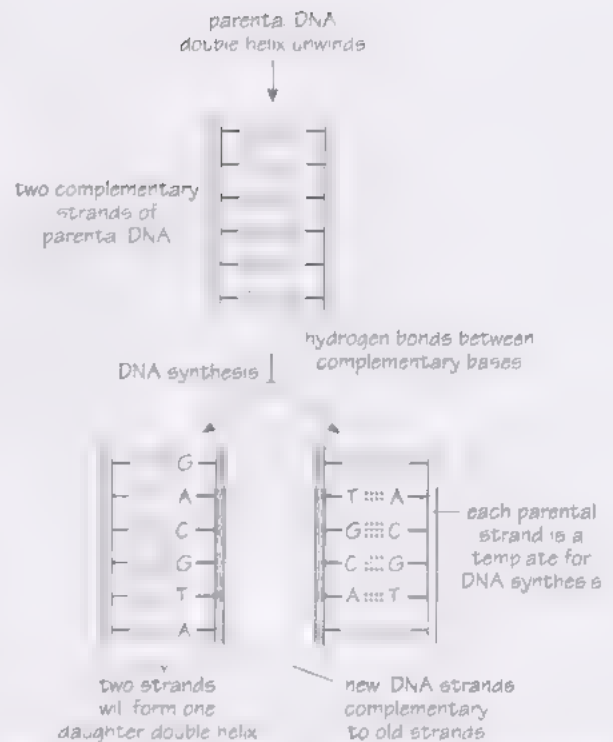


Figure 10.2.2 The process of DNA replication: each parent strand acts as a template for the synthesis of a new strand (This is the same diagram as that included in Answer 2 in the notes for this activity.)

Activity 11.1

The following is a list of key scientific points to be included, and one possible order in which they could be written up into a coherent account:

Transcription

- Transcription is the process of RNA synthesis; it transfers the code in DNA to RNA.
- Hydrogen bonds are broken — the DNA strands separate; one of these is the template strand
- Only part of the DNA molecule is transcribed.
- RNA polymerase adds nucleotides one at a time and the sugar-phosphate backbone is formed.
- Base-pairing rules of DNA to RNA.

Translation

- Translation is the formation of a polypeptide, or a protein, on mRNA.
- Four bases of mRNA are translated into 20 amino acids, the genetic code.
- Triplets of mRNA bases are the codons; each is translated into an amino acid
- Role of ribosome is to bind part of mRNA and two amino acids at a time
- Role of tRNA with its two specific binding sites — one for an amino acid and an anticodon that recognizes the codon in mRNA.
- Role of start codon.
- Two tRNA molecules bind to ribosome and a peptide bond forms
- Ribosome moves along the mRNA; a string of ribosomes forms a polysome.
- Role of stop codons.

(Note that these key points could be put together in other logical orders.)

The answer, given below, is based on the order of the key points given in the list. It would, with suitable diagrams (as used here), have been awarded full marks

Transcription is the process of RNA synthesis, in which information coded in DNA is transcribed into RNA (Figure 11.1.1). The hydrogen bonds of part of the DNA double helix are broken so that the two strands separate. Only one of the polynucleotide strands is used as the DNA template on which RNA synthesis occurs (Figure 11.1.1). RNA polymerase adds nucleotides one at a time according to the base-pairing rules: G binds to C, T of DNA binds A, and A of DNA binds U. The sugar phosphate backbone of the RNA molecule is formed.

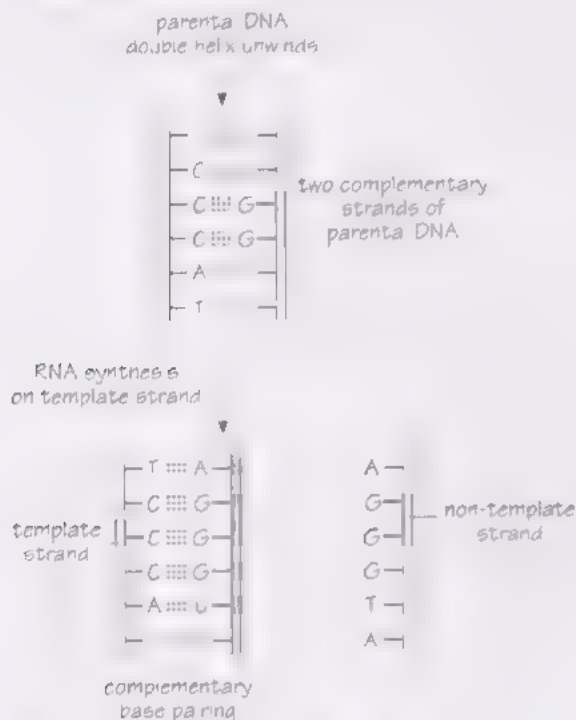


Figure 11.1.1 The process of transcription

Translation is the process whereby the four-letter language of mRNA is translated into the amino acid sequence of proteins. Triplets of bases of mRNA make codons, which are translated into 20 different amino acids. During translation, mRNA binds to a ribosome (Figure 11.1.2) and two tRNA molecules can also bind to it. The tRNA molecules carry amino acids and there is a different one for each amino acid. A codon of mRNA binds to an anticodon of a tRNA molecule, to which is attached a specific amino acid (Figure 11.1.2). The first codon has a particular sequence, known as the start codon, and codes for methionine. A second tRNA, with its attached amino acid, also binds to the ribosome, and a peptide bond forms between the two amino acids (Figure 11.1.2). The first tRNA molecule leaves the ribosome and the ribosome moves along the mRNA by one codon, leaving a vacant site for the next tRNA. The ribosome continues to move along the mRNA and the polypeptide chain grows progressively. A string of ribosomes can be attached to a single mRNA molecule and the structure is known as a polysome. Once the ribosome reaches the stop codon, translation comes to an end; ribosome and polypeptide leave the mRNA.

(310 words)

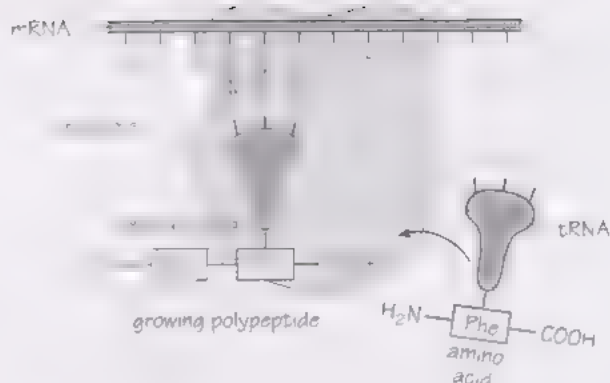


Figure 11.1.2 The process of translation

What did you achieve by doing this activity?

The activity asked you to think about which key points are needed to give an adequate explanation of transcription and translation. This required you to have a thorough understanding of the processes. The order of key points will not have been identical to ours, but if the points were similar, you have demonstrated a good understanding of transcription and translation.

Asking you to identify key points should help you to look closely at TMA questions in the future and to assess what is likely to be important in the answer. This in turn should enable you to become more critical of your own written work. Also, putting the key points in a logical order is an important part of *planning* your answers, a theme to which we return in later activities.

Finally, note that the model answer summarizes 5–6 pages of the book into two paragraphs. As in Activity 10.2, this sort of summary, especially if accompanied by appropriate diagrams, is useful for revision if you decide to study biology courses at a higher level.

Activity 11.2

(a) Template strand of DNA:

TACCTCCTCAATTCGGA...

RNA base sequence:

AUGGAGGAGUUAAGCCU...

(b) Sequence of RNA codons:

AUG GGA GGA GUA AAG CCU...

(c) From Figure 11.8d the following RNA codons can be related to specific amino acids:

AUG – Met; CCU = Pro; GCU = Ala,
GUU – Val; GGA = Gly; AAG = Lys.

This list was obtained by comparing the codon sequence (i.e. three bases at a time) in the mRNA strand in Figure 11.8 with the sequence of the six amino acids in the growing polypeptide chain.

Comparing these codons with the sequence of codons in part (b), the given DNA sequence codes for the following amino acid sequence:

Met–Gly–Gly Val–Lys–Pro–...

In this activity you have seen how six mRNA codons code for six amino acids in a polypeptide chain. This is a small part of the genetic code, which is discussed more fully in Section 11.5.

Activity 11.3

(a) The mRNA sequence will be:

AUGGAGCCAGUAGGGA...

(b) The amino acid sequence will be:

Met-Glu-Pro-Val-Gly-...

Notice that this is only the start of the amino acid sequence. We cannot say what the last 'A' base might be part of the code for, since two thirds of the codon is missing

(c) The DNA sequence of the non-template strand is:

ATGGAGCCAGTAGGGA...

(d) The mRNA transcribed from the non-template strand would have the sequence:

UACCUCGGUCAUCCCU...

(e) The amino acid sequence corresponding to the mRNA sequence in (d) would be:

Tyr-Leu-Gly-His-Pro-...

Notice that if the non-template strand of DNA were to be transcribed, and the mRNA subsequently translated, a completely different amino acid sequence would be synthesized. Compare this sequence with the answer to (b) above.

(f) The template strand produced AUG as the first mRNA codon, which is the start codon and codes for methionine. In contrast the mRNA that would result from the transcription of the non-template strand of DNA would have UAC as its first codon. In practice, therefore, this mRNA would not be translated into a polypeptide chain.

Activity 11.4

In this activity you reviewed the structure of DNA and RNA, and the processes of DNA replication, transcription and translation. You have seen how the first two of these processes relate to the structure of DNA as a double helix, and how the information carried in DNA is translated — via mRNA — into a sequence of amino acids in a polypeptide chain. In this DVD-video sequence, the information coded in DNA is likened to the printed characters in a pile of telephone directories. In the cell, only a portion of this information (i.e. only some genes) is required to be translated into proteins. In the analogy, this portion is represented as a page in a telephone directory and the information it contains can be transferred either by being removed (torn out), in which case some of the information is lost, or by it being copied as a photocopy, in which case the information in the directories is left intact. In the cell, the information in DNA is transferred, not by being removed, but by being copied — a 'photocopy' — in the form of mRNA, and the entire information in DNA is left intact.

The notes you added to the comments section of the list will reflect whatever you personally found useful or visually striking, and therefore will help you to remember the key points of the DVD-video.

Activity 11.5

The original DNA sequence coded for the following sequence of amino acids:

Met-Glu-Pro-Val-Gly

(See comments for Activity 11.3.)

(a) The new DNA sequence is given as:

TACCTGGTCATCCCT...

After transcription, the mRNA sequence would be:

AUG GAC CAG UAG GGA ...

After translation, the amino acid sequence would be:

Met-Asp-Gln-stop-Gly-...

The significant feature here is that a mutation has resulted in a stop codon in place of the fourth amino acid in this sequence. Since translation would terminate at the stop codon, an incomplete — and therefore non-functional — polypeptide would be produced.

(b) The new DNA sequence is given as:

TACCCTCGGTCATCCCT...

After transcription, the mRNA sequence would be:

AUG GGA GCC AGU AGG GA...

After translation, the amino acid sequence would be:

Met-Gly-Ala-Ser-Arg (Asp or Glu)-...

Notice that because the last codon is incomplete, we cannot be sure which of either Asp or Glu is the sixth amino acid

The significant feature is that this mutation has brought about a large change in the resultant amino acid sequence as a consequence of insertion of a single base base. Only the first amino acid is the same as in the cells that were not treated with the mutagenic agent (as in Activity 11.3).

Activity 12.1

The genomes and gene function in prokaryotes and eukaryotes are very different, as Table 12.1.2 (*overleaf*) shows. This is another example of how a large amount of information can be neatly and briefly summarized in a table

Activity 13.1

The completed paragraphs are given below. Inserted words are *italicized*.

Over time, each generation of organisms is replaced by a new generation. For any particular character, if all the individuals have identical *phenotypes*, then this process of replacement has no effect. However, many characters are *polymorphic*, that is, they exist in two or more alternative forms. These forms may change in their *relative frequencies* between generations, by one of two principal mechanisms of evolutionary change: *genetic drift*, whereby a character may increase or decrease in frequency due to chance events, and natural selection, whereby some characters are more likely to survive than others. *Mutations* provide the raw materials on which *genetic drift* and natural selection can act.

Table 12.1.2 Completed version of Table 12.1.1: comparison of genomes and gene function in prokaryotes and eukaryotes

Feature	Prokaryotes	Eukaryotes
genome complexity	simple	complex
site of DNA replication	cytosol	nucleus
site of transcription	cytosol	nucleus
site of translation (ribosomes)	cytosol	cytoplasm*
introns	absent	present
exons	absent	present
split genes	absent	present
repeat sequences	absent	present
mRNA splicing	absent	occurs

* Strictly, translation in eukaryotes occurs on ribosomes attached to the rough endoplasmic reticulum (see Section 2).

The essence of Darwin's theory is that natural selection will operate if three fundamental criteria are met. First, individuals within a *population* must show *phenotypic* variation. Second, some of this *phenotypic* variation must be due to *genetic variation* and hence have a *heritable* basis. Third, there is a *struggle for existence* so that, on average, more or fewer individuals of one *phenotype* must survive than those of another. Natural selection favours the *phenotype* (e.g. brightly coloured male guppies) that results in most offspring surviving to maturity. *Fitness* is the numerical measure of relative reproductive success.

These two paragraphs summarize two sections of text from Block 4, and, therefore, are a useful revision aid.

Activity 13.2

(a) The genotypes of the gametes produced by the left-hand cell are AB , AB , ab , ab in a ratio of 1:1:1:1 (i.e. $1AB:1ab$) because homologous chromosomes separate (segregate) from each other during meiosis. The genotypes of the gametes produced by the right-hand cell are aB , aB , Ab , Ab , again in a 1:1:1:1 ratio (i.e. $1aB:1Ab$). Because chromosomes assort independently during meiosis, the gametes ab and AB will be produced in about half of the meioses and aB and Ab in the other half. Hence the overall ratio is $1AB:1ab:1aB:1Ab$. The recombinant genotypes would be aB and Ab . The other two genotypes, AB and ab , are the same as those originally inherited from the individual's parents.

(b) Following crossing over, the first meiotic division would produce cells with chromosomes that have chromatid genotypes (De and DE) and (de and dE) and the second meiotic division would produce four cells, each containing one chromatid (now a chromosome), with genotypes: De , DE , de and dE . In this case we cannot determine the ratio of the four types because this would depend on the amount of crossing over along the chromosome between these two loci; during some meioses there would be no crossing over between these two loci and hence only the parental genotypes would be produced. We can say that the ratio of De to dE is 1:1, and the ratio of DE to de is 1:1. The recombinant genotypes are DE and de , since these result from crossing over of the two chromatids; the parental genotypes are as illustrated on the non-cross-over chromatids, De and dE .

These two paragraphs, and the related diagram in the notes for this activity, clearly summarize genetic

recombination, and again will be useful for revision purposes.

Activity 13.3

The answers to the questions are given below.

Question 1 The mutation would have arisen at random. Evolution has to use whatever mutations are available to it, so once the Hb^s allele had arisen it would have been selected for in areas where malaria is prevalent.

Question 2 The answer lies in the resistance of the heterozygotes Hb^sHb^A to malaria. Those parts of the world where the Hb^s allele is common also have high frequency of malaria, and the parasite finds the red blood cells of individuals with sickle-cell trait 'inhospitable'. So such individuals have some resistance to malaria, as compared to $Hb^A Hb^A$ homozygous individuals, and hence have an evolutionary advantage.

Question 3 The evolutionary advantage conferred by the Hb^s allele would be lost in individuals living in the USA where there is no malaria, so the allele would be expected to wane in frequency. Heterozygous Hb^sHb^A individuals would no longer be at an advantage compared with $Hb^A Hb^A$ individuals; indeed such individuals would be at a mild disadvantage as, having a mixture of normal and abnormal haemoglobin, they would suffer from mild anaemia. Homozygous Hb^sHb^s individuals would still die early and so the Hb^s allele would gradually decline in the population. So in environments where there is no malaria, $Hb^A Hb^A$ individuals are fitter than both homozygous Hb^sHb^s individuals and heterozygous Hb^sHb^A individuals.

Question 4 The polymorphism is called a balanced polymorphism. The balance is maintained by the relative costs and benefits incurred by the various genotypes (and their associated phenotypes). In the case of sickle-cell disease, persons homozygous for Hb^A are susceptible to malaria; those who are homozygous for Hb^s die from anaemia; those who are heterozygous have mild anaemia and resistance to malaria.

It is worth making some comments on the programme. The high frequency of the allele Hb^s in a population is attributable to its link with malaria. The tying together of this connection is historically a classic example of 'scientific detective work'. The scientific and medical consequences of understanding both these diseases and the social consequences, such as the attempted

eradication of malaria (see 'A formidable foe') and the screening for sickle-cell disease both in Africa and the USA (this programme), powerfully illustrate the interaction between science and society. Screening of babies at birth ensures an early programme of treatment for affected individuals and education of parents and communities, in order that they can give support for this treatment. The work of various worldwide bodies involved in studying and promoting awareness of malaria and sickle-cell disease provides good examples of the need to disseminate scientific information, and of the problems and successes associated with this process.

Activity 13.4

(a) You have thought about different writing styles previously in S103. For example, in Block 2 Activity 10.3 you planned a letter to a local newspaper, and you have probably written a report of an experiment for a TMA. What is required in this account about sickle-cell disease is different again. The health visitors need *facts*, presented in a logical manner (as outlined in Section 2.1 of Chapter 9 of *SGSG*).

(b) Here is an example of a plan for the account

Introduction (setting the scene) Genetically determined, where disease is found and why

Main body

Paragraph 1: Genetics of the disease — alleles and pattern of inheritance — sickle-cell disease, $Hb^A Hb^A$; sickle-cell trait, $Hb^A Hb^S$.

Paragraph 2: Reason for the persistence of the disease in Africa — malaria — heterozygous advantage

Paragraph 3: Prevalence of the disease in Britain — brought by grandparents from central Africa, maintained because genetically transmitted — $Hb^A Hb^A$ heterozygotes have no advantage, so prevalence likely to be reduced

(Note that there are a number of equally coherent ways of organizing the material in the main body.)

Conclusion (summary of key points) Prevalence linked to environment — presence or absence of malaria.

(c) We used the plan in (b) to write the following account.

Sickle-cell disease is a genetically determined disease, commonly found in tropical regions of the world where malaria is rife, such as India and central Africa. The link between sickle-cell disease and malaria explains its high frequency in these parts of the world.

The disease affects haemoglobin. The gene that codes for haemoglobin is designated Hb , with the normal version of the gene designated Hb^A and the mutant, or disease, allele as Hb^S . Unaffected normal individuals inherit two copies of the normal allele and are designated $Hb^A Hb^A$. Full symptoms of the disease, that is, sickle-cell disease with anaemia and with the majority of red blood cells sickle-shaped, are manifest in individuals who have two mutant alleles, $Hb^S Hb^S$. Affected children are born to parents who are both heterozygotes for the disease; they each carry one normal and one mutant allele, $Hb^A Hb^S$, and they have sickle-cell trait because the two alleles show incomplete dominance. Heterozygotes have mild

anaemia and red blood cells that sickle under certain conditions, but which are inhospitable to the malaria organism. On average, one quarter of the children of parents both of whom have sickle-cell trait will have sickle-cell disease, half will have the sickle-cell trait, and a quarter will not carry the disease allele.

The disease allele would have been brought by the parents and/or grandparents of the current Afro-Caribbean population when they emigrated to Manchester from Africa. There the disease has a high prevalence because of its link with malaria (see Figure 13.6 in the book). Individuals with sickle-cell disease die before they have children, but the heterozygotes have a large advantage over normal homozygotes because they are better able to overcome malaria. This is summarized in the technical term 'heterozygous advantage'. Heterozygotes are less susceptible to malaria because the parasitic organism that causes the disease (*Plasmodium falciparum*) lives in red blood cells and is not able to reproduce in sickled red blood cells as successfully as in normal red blood cells. The consequence of heterozygous advantage is that the mutant allele is maintained in the population in high numbers.

Individuals with sickle-cell trait living in Manchester lead a more or less normal life. Half their gametes will carry the disease allele and half will carry the normal allele. If their partner is unaffected, then on average half of their children would be heterozygotes. On the other hand, if their partner also has sickle-cell trait, then again on average half of their children would be heterozygotes, but a quarter would not carry any disease alleles, and a quarter would have two copies of the disease allele, so they would have sickle-cell disease. Heterozygotes maintain the mutant allele in Britain, even though individuals with sickle-cell disease tend to die before they themselves reproduce.

In conclusion, sickle-cell disease is a genetic disease manifest in homozygous recessive individuals. It is present at high frequencies in the parts of the world where malaria is prevalent because heterozygotes have an advantage over both types of homozygote and are more likely to survive and have children. When these people emigrate to regions of the world where malaria is absent, the heterozygous advantage is lost. However, heterozygotes continue to transmit the mutant allele to half their children. (587 words)

It is worth making some comments on this answer. You may have found it difficult to decide both on the amount of detail to include in the account and the choice of language when writing for such an audience. The author of this answer chose to follow the advice given with the question about assumed knowledge of genetics, and used the technical terms without explanation. But you may have defined the genetic terms used, and we appreciate that this would have increased the length of the account. Also, you may have included a mating diagram, which would have been good practice.

Note that the author avoided the use of the term 'probability' since it could not be assumed that the readers understood this concept, and explained the term 'heterozygous advantage', which was important because it only applies to certain genes. You may have included the point made in the DVD-video, that the

evolutionary advantage conferred by the *Hb^S* allele would be lost in individuals living in Britain where there is no malaria, so the allele would be expected to wane in frequency. In which case you should congratulate yourself!

Finally, having completed writing your account, did you use the review checklist given in the comments for Activity 10.1? If not, try to remember to do this next time. We will discuss further the approach to producing written answers, including producing a plan, in Activity 15.1, part (a).

Activity 14.1

The following is an abbreviated version of the summary given on the DVD-ROM

Part 2: Evolution in Real Time

In this part you explored the concept of evolution by natural selection. The amount and type of food available is affected by climate and by competition with other species. Beak size varies between species of Darwin's finch and between individuals within each species, and influences the kind and size of food, particularly seeds, that a bird can eat

If small seeds are in short supply, birds with larger beaks have more food available to them than birds with smaller beaks and are more likely to survive and reproduce. This leads to an increase in mean beak size for that species in the next generation. If large seeds are in short supply, the reverse occurs, and leads to a decrease in mean beak size for that species in the next generation.

Natural selection can operate on very subtle differences between individuals — a difference in beak size of as little as 0.5 mm can mean the difference between dying or surviving — and evolutionary change can take place in a species in only a few generations.

Part 3: Species and Speciation

In this part you explored the concept of speciation, the process by which one species splits into two or more species. Species now endemic to the Galapagos Islands probably evolved after colonization by plants and animals from the mainland

Initial differences between mainland and island populations of a particular species would have resulted from the founder effect. The geographically separated populations would have experienced different mutations, adapted to different local conditions and been affected by genetic drift in different ways. Eventually they became so different that they are now classified as separate species. Repeated colonization and recolonization events between islands would have resulted in populations being repeatedly separated geographically, leading to the formation of many new species. Divergence between separate populations is slowed down by interbreeding between them, which is more likely if islands are close together. Thus isolated islands are more likely to have endemic species.

Activity 15.1

(a) Reviewing your study of Block 9: learning to be a good judge

(i) Assessing your own work

In general terms, the criteria by which you should judge your work fall into two groups. First, there are the criteria by which the science content is judged: correct information, relevant to the question, answering the question set, and so on. To set up these criteria for a specific question requires knowledge of the science involved. Second, there are criteria by which the writing is judged: a logical structure, clear and concise writing, and appropriate style and language for the audience.

We produced the following criteria by which to judge a written answer to an activity or an assignment.

Science

- science should be correct
- complete coverage of main points, with appropriate explanation
- suitable diagrams included, correctly labelled, with a title, and referred to from the text

Writing

- clear and easy to read, without ambiguities
- concise — without repetitions; with the appropriate level of detail
- written in a suitable style for the particular audience, such as a fellow student or tutor
- uses the approach required by the question, e.g. 'discuss', 'compare and contrast'

Length

- within the suggested word limits

(ii) Writing long scientific accounts

Only you can decide how effective your sequence of working is. However, here are comments from two S103 students about how they go about writing long accounts, and the advice that they would give themselves. These comments are followed by some suggestions from an experienced tutor, which you may find helpful

First student's comments

I read the TMA question before I begin reading the block, and gather material over a prolonged time, making notes of anything that seems relevant as I work through the block. This works well, and saves me time going back to the block after I have finished studying it. I generally just sit down at my computer and start typing — writing up the notes that I made whilst studying. I think this prevents my anxiety about not doing a good enough job on the answer from building up because I know I don't have to get it right from the word go. I change things around and sort it out once I've got something down. I just stick down the ideas/contents of each paragraph and then work them up individually, and sort the paragraphs out into a logical order later on. But changing the order often requires me to rewrite some paragraphs. Sometimes I get stuck, but then it's about some specific information, and I go and look it up. Also I check whether I have omitted something —

unfortunately inserting a new point often means that I have to rewrite some of my account again to fit it in. I spend time reading over what I have done, moving it into an order that makes sense, and rephrasing it, often adding more details. I sometimes spend too long on this, because I work over it again and again to try and improve it; sometimes I make it worse, by adding too much detail and going past the word limit.

My advice to myself about the way I should tackle the next written account is

- Continue to make notes of the relevant science as I work through the block.
- Make a start on the writing in good time.
- Try to find anything I have omitted before starting to write
- Use cut and paste on the computer to put all of the points into a logical order before writing them out in full, i.e. produce a sort of working plan.
- Once I've produced the first draft, tidy it up by putting in links and signposts, and make the phrasing more concise.
- Read it over, and think about whether the style is OK.
- Put it in the post even if I don't think it is perfect.

Second student's comments

I like to think all about the subject before I begin. I read over the relevant parts of the blocks several times, and, if I can, I read from another source too. Sometimes I talk it over with other students, or even tell a member of my family about it: it's amazing how interested they have been. I quite enjoy the time I give to this step but I probably spend too long on this — I realize that what I am doing is putting off the actual writing. Then I like to go out for a long walk with the dog, and when I come back, I sit down and write. I think my writing is far more fluent if I just sit and write. The problem is that my ideas are not presented in the best order, so I then rework the order of the material to make it more logical and this takes time. I sometimes have a problem sticking to the word limit, but I find if I worry about this too much, I end up cutting out some science that should be in there, and then I lose marks for that.

My advice to myself about the way I should tackle a written account is.

- Research the topic and talk it over with other people, but set a time when I'll start to write.
- At that time, make a plan so that I get the material into a coherent order before I begin to write, and hopefully see if there's anything else I need to find out.
- Try to use diagrams to reduce the word length.
- A few days later, read the account out loud to identify redundancies and see if it fits together OK. Use the review checklist from Activity 10.1.
- Ask a friend, or family member, to read it over and give me comments.
- Make any changes, then write out the final version.

Suggestions from a tutor

There are many different ways of producing a long scientific account, and what matters is that you develop your method so that you can produce answers of the standard you want. It might help you to ask yourself the following questions:

(a) What is the question asking me to do?

The first step is to analyse the question. Underline or highlight process words like 'discuss' or 'compare and contrast' that tell you what you have to do with the material. Then underline/highlight the words that tell you which concepts in science you will be working with.

(b) On what science does this question depend?

Next you need to research the science. You will find the information you want by searching in glossaries, summaries, indexes, contents pages, questions, activities, your notes, and (if you have time) outside sources such as other students, books, articles, etc.

(c) How am I going to put it all together?

We have encouraged you to plan longer pieces of written work before you start writing. However, research amongst both tutors and students reveals that the actual process of getting an account onto paper takes many different forms, and may not follow the traditional process of 'first make a plan'. The boon of being able to rearrange sentences and paragraphs with a word processor means that a even a very poorly thought out first draft can still be turned into what appears to be a well-planned essay.

What is essential is that you decide what to include and what to leave out, and how to link the points that you include so that they answer the question that was set. Noting down your decisions as a plan, or outline, gives you a framework within which you can construct your account. Of course, you may change your ideas about content or order as you're writing, but that will be easier to do if you have a plan in front of you. And if you have an overall structure for your answer in mind, then it is much easier to tell a coherent story, and you won't have to spend so much time rejigging your answer later. What you should be aiming for is an account that is presented in a good order, written clearly and concisely, in appropriate language, with signposts and links between the different points to make it easy for your tutor to read.

(d) How can I improve my written work?

You may find it useful to go through a review checklist, such as the one in the comments on Activity 10.1. Also you may like to ask yourself what mark you would give yourself, and why — i.e. try to be critical. Of course, to work systematically and thoughtfully through your answer, improving it as you go, requires that you set aside sufficient time, and that means not leaving completion of your answer until the day before the cut-off date!

One last point, an assignment is not finished until you receive feedback from your tutor. This feedback is designed both to sort out any science that is missing or incorrect and to offer you general advice on how to improve your answers. You should read this carefully, and integrate it into your own advice to yourself about how to tackle the next assignment.

(b) Reviewing your revision

(i) Here is a summary of the methods of revision used in activities in Block 9:

<i>Activity 2.1</i>	Completing a table
<i>Activity 3.1</i>	Writing definitions of terms
<i>Activity 3.2</i>	Applying knowledge to a new example
<i>Activity 4.1</i>	Describing or explaining something in one sentence
<i>Activity 8.1</i>	Identifying errors in a piece of writing and in diagrams
<i>Activity 10.1</i>	Writing a summary
<i>Activity 13.1</i>	Filling in gaps in a piece of writing
<i>Activity 13.2</i>	Identifying outcomes from illustrations of processes

Here is a list of the methods of summarizing used in activities in Block 9:

<i>Activity 5.1</i>	Completing a summary diagram
<i>Activity 5.2</i>	Producing a flow diagram
<i>Activity 9.1</i>	Producing a list with examples
<i>Activity 10.2</i>	Criticizing and improving summaries
<i>Activity 11.1</i>	Producing a list of key points
<i>Activity 12.1</i>	Completing a table.

(ii) Which of these methods you found useful is very much a matter of personal preference. We have drawn your attention to various methods of revising, and to different methods of summarizing as preparation for revising, so that you can consider which methods are most helpful for you.

Although revision is about consolidating your learning, it is particularly important as preparation for examinations, and you will have to tackle these in higher level courses.

1 In all previous blocks of S103, you have been encouraged to summarize material in different ways, e.g. as a short piece of writing, as a list, as a table, as a sketch, as a flow diagram, as a spray diagram. These techniques will be useful to you when you come to revise for examinations in the future. Remember that you will not have time to re-read a whole course in the weeks leading up to an exam!

2 Some of the revision activities in Block 9 have asked you to answer questions, and hopefully all of them have made you think! Actively engaging with the course material tends to be a more effective way of remembering material than passively reading it. The use of questions, for example the DVD-ROM Questions, is a valuable aid to revision.

3 Later blocks of S103 build heavily on earlier blocks (as Block 9 built on Blocks 4 and 8) so you are revising some of the course material as you go along. When you go back over concepts you have studied earlier in the course, you often find that they make more sense in the light of understanding gained later.

Objectives for Block 9

The objectives state what you should understand and what you should be able to do after studying the block.

The numbers of the questions and activities that test each objective are given in italics. In the margin next to some objectives are references to *The Sciences Good Study Guide* (SGSG), giving the chapter: section number or Maths Help (MH) number, where you can find additional help.

Science content

- 1 Explain the meaning of, and use correctly, all the terms printed in **bold** in the text.
- 2 Identify and explain the functions of the basic features of animal, plant and prokaryote cells, distinguish between these three types of cell, and describe the evolutionary relationship between them as proposed by the endosymbiotic hypothesis. (*Questions 2.1–2.3; Activities 2.1 and 7.1*)
- 3 Explain how biopolymers are formed from monomers, and name the types of monomer found in the three types of biopolymer: proteins, polysaccharides and nucleic acids. (*Questions 3.1, 3.4–3.6 and 3.8; Activities 3.1 and 10.1*)
- 4 Describe the relationship between the primary structure and higher-order structure, the role of weak bonds in this relationship, and the biological functions of the three types of biopolymer: proteins, polysaccharides and nucleic acids. (*Questions 3.2, 3.3, 3.5, 3.6, 3.8 and 3.9; Activities 3.2–3.4 and 10.1*)
- 5 Describe the components of triacylglycerols and phospholipids, and the relationship between structure and function of these molecules. (*Questions 3.7–3.9*)
- 6 Outline and identify the ways that enzymes resemble and differ from inorganic catalysts and the importance of the role that they play for metabolism in the living cell. (*Questions 4.1 and 4.2; Activity 4.1*)
- 7 Explain and recognize the role of coenzymes in the cell. (*Question 4.2*)
- 8 Describe energy transfer in living organisms and the role of ATP and ADP in the cell, and draw diagrams to show how an energy-releasing process is linked to conversion of ADP to ATP and how an energy-requiring process is linked to conversion of ATP to ADP. (*Questions 4.3–4.5 and 5.1; Activities 5.1 and 5.2*)
- 9 Describe the pathway of glucose oxidation and the main events of each of the four stages, including where these occur in the cell, the molecules present at the start of each stage, and the stages at which the molecules of carbon dioxide, NAD₂H, and ATP are produced. (*Questions 5.2–5.5; Activities 5.1, 5.2 and 7.1*)
- 10 Identify the structures in the inner mitochondrial membrane, and describe the processes that occur at this membrane as proposed by the chemiosmotic hypothesis. (*Questions 5.4–5.6; Activities 5.2 and 7.1*)
- 11 Describe how the *aerobic* breakdown of glucose releases more energy than its *anaerobic* breakdown. (*Activity 5.1*)
- 12 Relate the catabolism of fats and proteins to common routes of catabolism in the central pathway, and relate catabolism to biosynthesis. (*Question 5.7*)
- 13 Outline the control mechanisms involved in maintaining an energy supply for cells in mammals. (*Question 5.7*)
- 14 Describe the light and dark reactions and relate each of these to the overall process of photosynthesis. (*Questions 6.1–6.3; Activity 7.1*)
- 15 Compare glucose oxidation and photosynthesis, including comparison of oxidative phosphorylation with photophosphorylation. (*Question 6.4; Activity 7.1*)

- 16 Interpret simple breeding experiments involving a single pair of contrasting characters, in terms of the genotypes and phenotypes of parents and offspring, and their ratios. (*Questions 8.3–8.9, 9.1–9.3; Activities 8.2 and 8.3*)
- 17 Explain where segregation, independent assortment, crossing over and linkage occur during meiosis, and determine the effect of each of these on the distribution of copies of genes, and alleles, among gametes. (*Questions 8.5, 8.7, 8.10, 8.11 and 9.2; Activities 8.2, 8.4 and 13.2*)
- 18 Compare mitosis with meiosis. (*Question 8.1; Activities 8.1 and 8.4*)
- 19 Explain and recognize the factors that contribute to phenotypic variation between individuals of a species. (*Questions 8.2, 9.1–9.3 and 14.3; Activities 8.4, 9.1–9.3*)
- 20 Give a brief account of the structure of DNA, and how this structure explains the stability of the molecule, how it replicates and how it carries genetic information. (*Questions 10.1 and 10.2; Activities 10.2, 11.2, 11.3 and 11.5*)
- 21 Describe the structure of RNA, and explain how this differs from the structure of DNA. (*Questions 11.1 and 11.2*)
- 22 Outline the roles of DNA, mRNA, tRNA and ribosomes in the processes of transcription and translation. (*Question 11.3; Activities 11.1 and 11.4*)
- 23 Determine the sequence of amino acids in the polypeptide that is produced from a specified sequence of DNA bases, using the base-pairing rules and given relevant information about the genetic code. (*Activities 11.2, 11.3 and 11.5*)
- 24 Explain how mutation can change the order of DNA bases and hence change the primary structure of proteins. (*Activity 11.5*)
- 25 Describe how mRNA produced on a split gene can be modified after transcription. (*Questions 12.1 and 12.2*)
- 26 Compare and contrast prokaryotes and eukaryotes in terms of their genomes and gene function. (*Question 12.3; Activity 12.1*)
- 27 Describe evolutionary change over time, both in terms of changes in the external appearance or behaviour of organisms, and also in terms of changes in allele frequencies. (*Questions 13.2 and 13.4; Activities 13.1, 13.3, 13.4 and 14.1*)
- 28 Discuss, using the examples of human blood groups, the peppered moth and sickle-cell disease, the possible role of natural selection in determining the relative frequencies of different alleles. (*Questions 13.2–13.4; Activities 13.3 and 13.4*)
- 29 Describe the role of mutation and recombination in causing and maintaining genetic variation in natural populations. (*Questions 13.1, 13.2, 14.1–14.3; Activity 13.2*)
- 30 Explain how the Red Queen effect, the founder effect and a genetic bottleneck affect evolutionary change. (*Questions 14.3 and 14.6; Activity 14.1*)
- 31 Describe how new species can evolve by the processes of allopatric speciation or of sympatric speciation — including polyploidy — and explain the difference between the two processes. (*Questions 14.4 and 14.5; Activity 14.1*)
- 32 Distinguish between factors that can promote genetic divergence and those that can prevent genetic divergence between populations. (*Question 14.6; Activity 14.1*)
- 33 Explain the importance of polyploidy in evolution and in agriculture. (*Question 14.5*)

Science skills

- 34 Perform a biological project involving fieldwork by collecting material, analysing it and interpreting the results. (*Activity 1.1*) SGSG 6: 4
- 35 Interpret scientific data presented in various ways. (*Activities 1.1, 8.3 and 14.1*)

Communicating science skills

- 36 Critically assess your own and others' scientific answers to assignment questions for accuracy and style. (*Activities 3.3, 8.1, 10.1, 10.2, 11.1 and 15.1a*) SGSG 9: 5
- 37 Plan the content and organization of a long account. (*Activities 11.1 and 13.4*) SGSG 9: 5
- 38 Write for a particular audience or purpose. (*Activities 3.3, 10.1 and 13.4*) SGSG 9: 2
- 39 Use diagrams as part of an explanation or an answer to a question. (*Questions 3.1, 8.6, 8.7 and 9.1; Activities 3.3, 5.2, 8.1, 8.2, 9.2, 9.3, 10.1, 10.2, 11.1 and 13.4*) SGSG 3: 4–5

Mathematical skills

- 40 Determine ratios and probabilities and explain why observed and predicted ratios in biological material may differ. (*Questions 8.5–8.7, 8.9, 8.10 and 9.1; Activities 8.2–8.4, 9.2 and 13.2*)

Effective learning skills

- 41 Revise and integrate information from an earlier block or an earlier section of this block. (*Activities 2.1, 3.1, 3.2, 4.1, 8.1, 10.1, 13.1 and 13.2*)
 - 42 Summarize important concepts in a paragraph(s), using a flow diagram, a table or a list, and reflect on their usefulness for revision purposes. (*Activities 5.1, 5.2, 9.1, 10.2, 11.1, 12.1 and 15.1b*) SGSG 10: 5.7
 - 43 Solve problems by using appropriate strategies and relevant principles. (*Activities 8.2, 9.2 and 9.3*)
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Appendix What to do if you are short of time

This brief guide to the activities in Block 9 should help you to decide for yourself whether you need to do a particular activity. Remember, though, that if you have the time you should aim to do *all* the activities in order to obtain the full benefit from your study.

The four numbered columns in the table below offer advice about each activity as follows:

- 1 essential that you do this activity at the particular point in Book 9 where it appears;
- 2 important, but there is more flexibility about when you do this activity, although you should try to complete it before moving onto the next section of Book 9;
- 3 may not be essential if you have some background already in the topic or skill, or have found earlier, similar activities straightforward;
- 4 could be left until later on, or dropped altogether if you are really short of time;

The last column on the right contains additional advice about some of the activities.

Block 9 activities

Activity	Category				Comments
	1	2	3	4	
1.1				✓	
2.1			✓		
3.1			✓		
3.2			✓		
3.3			✓		
3.4				✓	
4.1			✓		
5.1	✓				Comments useful for revision
5.2				✓	Comments useful for revision
7.1		✓			Part 3 'photosynthesis' could be omitted
8.1			✓		
8.2		✓			
8.3			✓		
8.4		✓			
9.1	✓				
9.2		✓			If you found Activity 8.2 straightforward you could leave Activities 9.2 and 9.3 until you come to revise.
9.3		✓			
10.1			✓		
10.2				✓	
11.1			✓		
11.2				✓	
11.3		✓			
11.4		✓			
11.5	✓				
12.1		✓			Comments useful for revision
13.1			✓		
13.2			✓		
13.3				✓	
13.4			✓		
14.1			✓		Useful for revision
15.1		✓			